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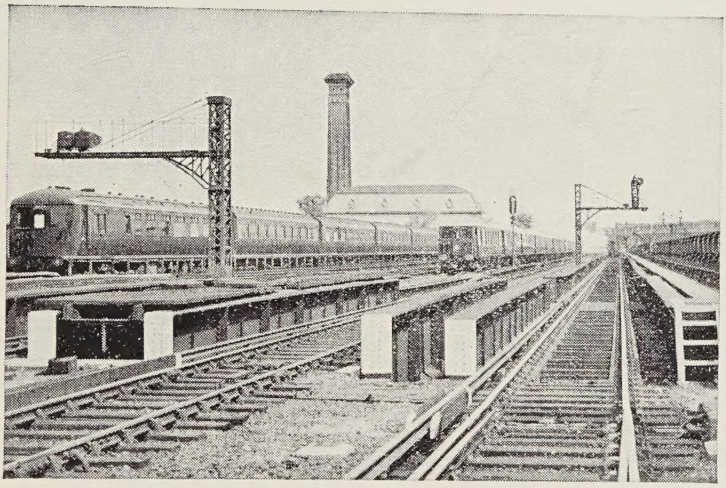

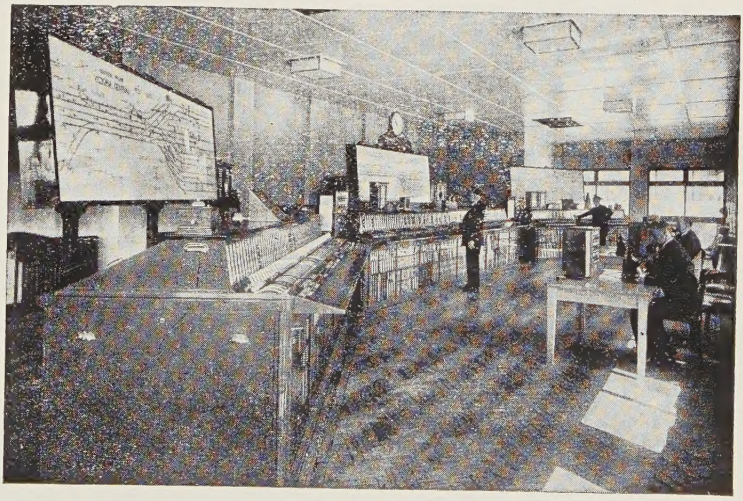

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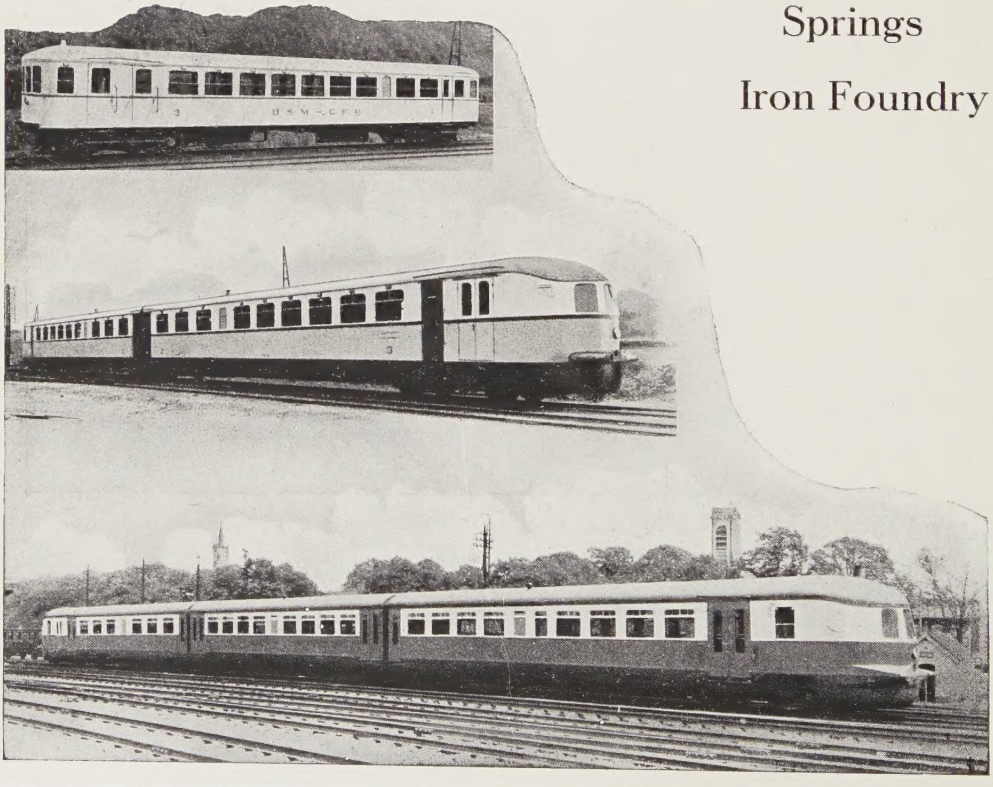

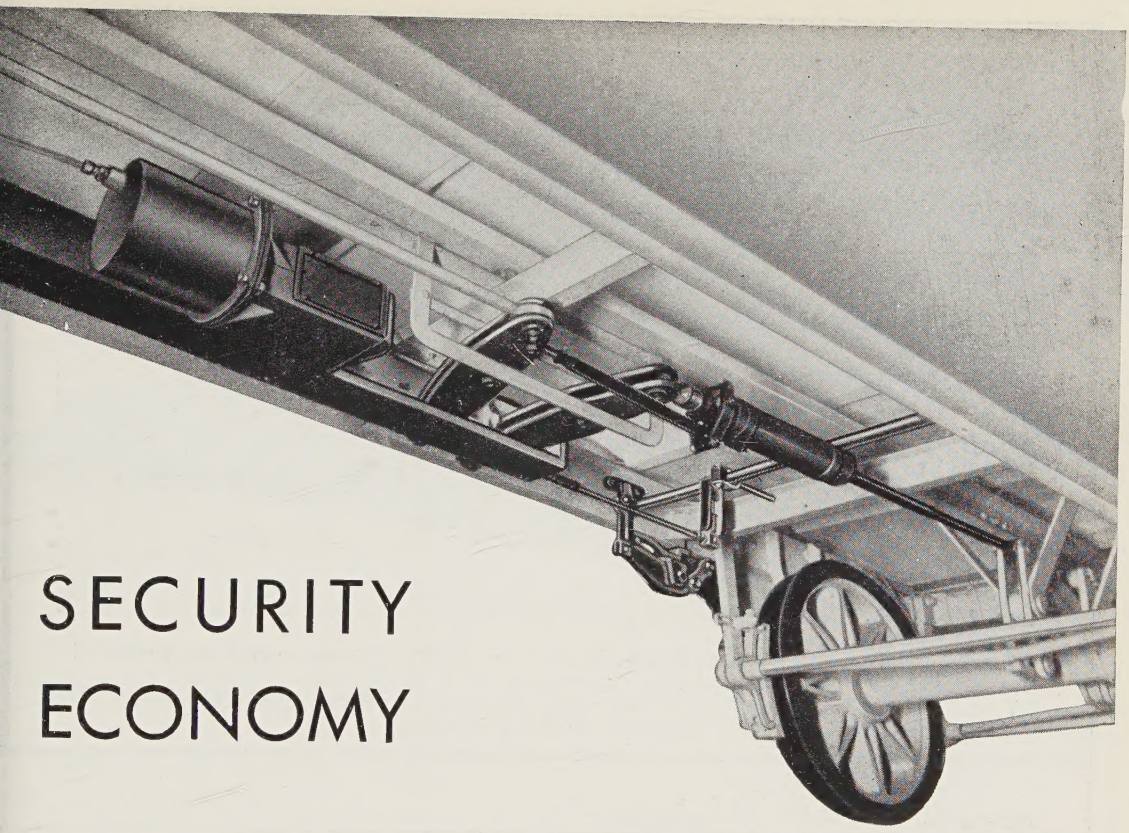

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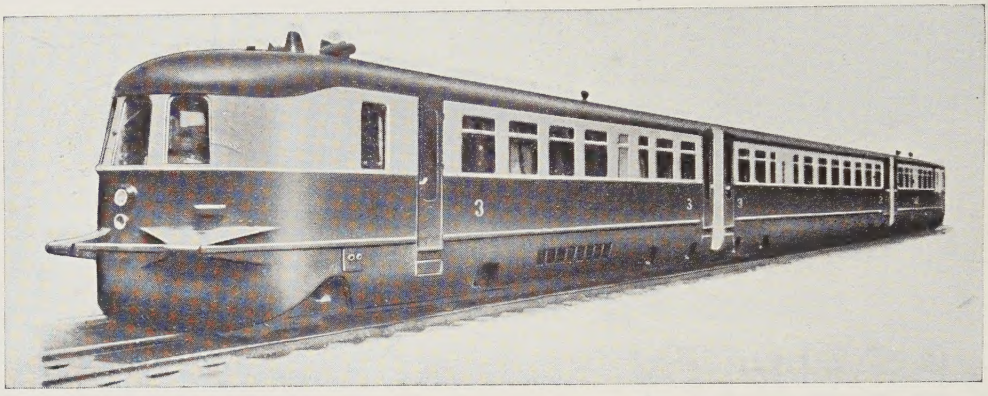

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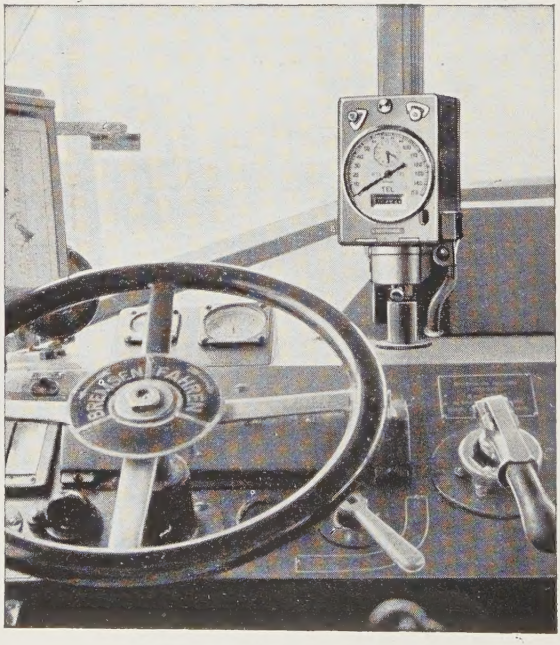

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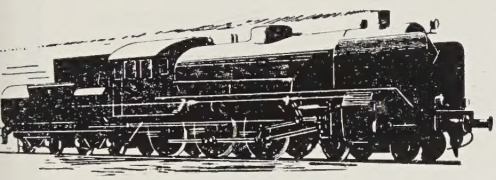

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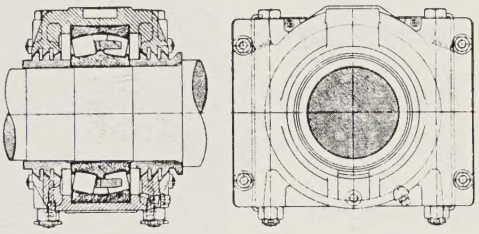
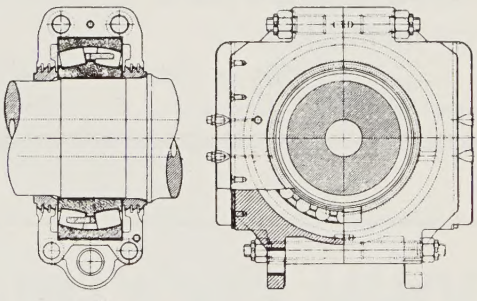
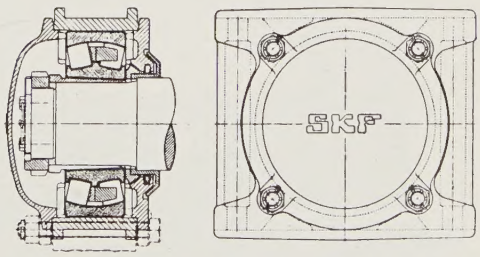


Axlebox of leading bogie



Axlebox of driving axle and coupled axles



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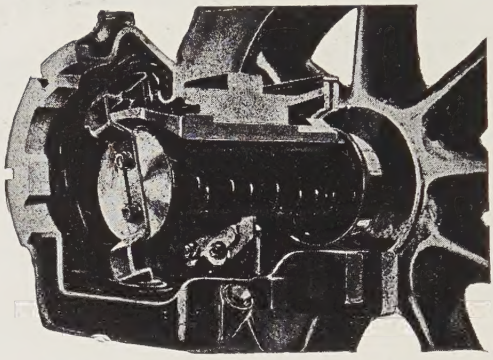

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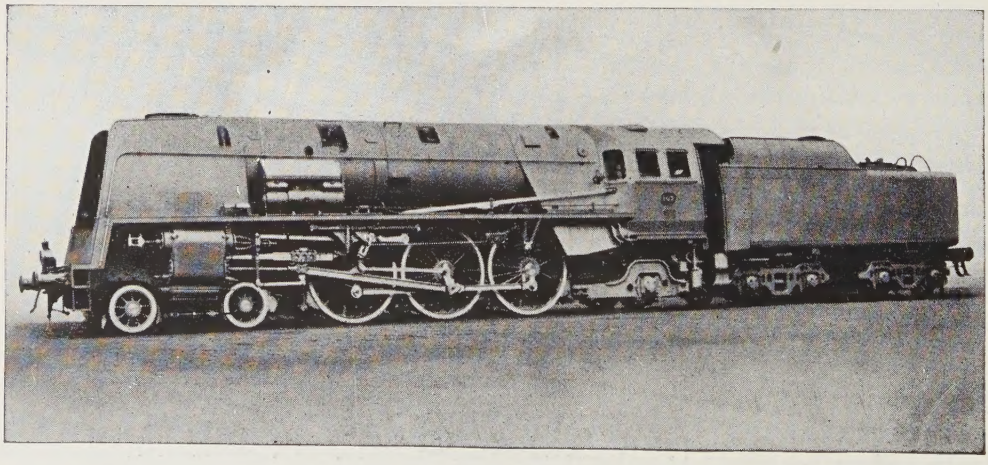

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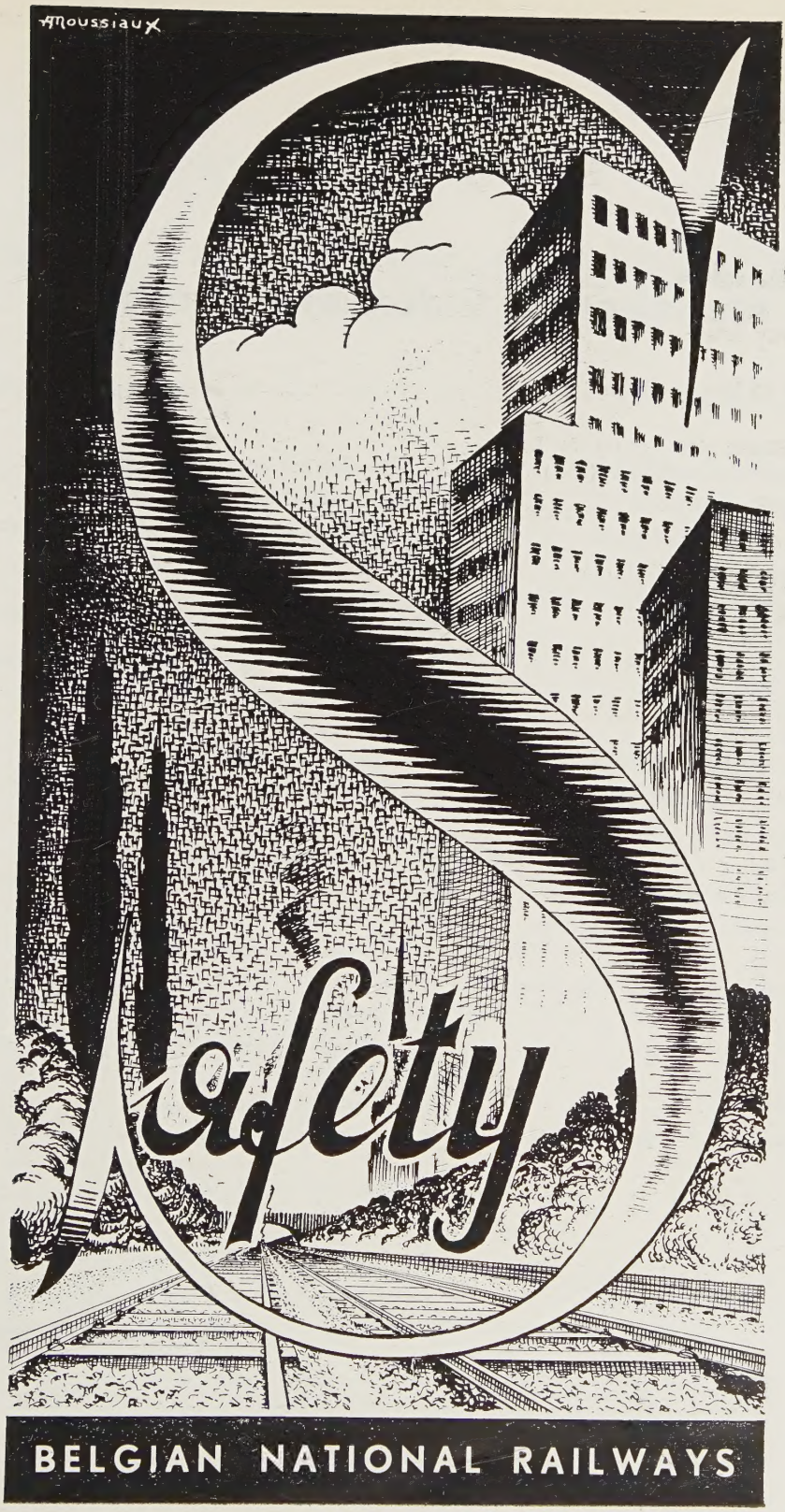
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MONTHLY BULLETIN

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VOL. XXIV. — No. 9. September 1947.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[621 .337]

Individual axle drive.

Mechanical systems used on electric locomotives and railcars, with an indication of the results obtained in service on railways of all kinds,

by ADOLPHE-M. HUG,

Consulting Engineer, of Thalwil, (Zurich) Switzerland.

INTRODUCTION.

An earlier survey of this subject by the present author was published in the French edition of the *International Railway Congress Bulletin* in March, 1930 (appearing in the English edition in June, 1930, and in the German edition in September, 1930) on the occasion of the *International Railway Congress*, in Madrid in 1930.

At the request of several Administrations, the Author undertook in the same year a much more detailed examination of the subject, which was amplified to include systems introduced between 1930 and 1932 and appeared in the review *La Traction Electrique*, Nos. 1, 4 and 7, in 1931, and No. 8, in 1932. This latter survey, revised and amplified, was published in 1933 in the form of a 112-page bound volume (with 202 illustrations, complete bibliography and a French-German-English dictionary of the principal technical terms) by the firm of Orell-Füssli, of Zurich (Switzerland) and Leipzig.

The present article brings *up-to-date* the work mentioned above, the foreword to which was compiled by. M. W. MÜLLER, at that time — and until 1944 — Chief Engineer for Motive Power and Workshops of the Swiss Federal Railways (SBB-CFF-SFF), Berne.

In this supplement for 1946/47 we shall, after noting certain general tendencies, examine successively all the systems of individual axle drive which have appeared since 1932, at least insofar as they have been used in railway operation. So as to give a better view of the whole field, the succession of mechanical systems described will not be dealt with cronologically, but will be dealt with wholly by classes, as in the preceding articles and the work mentioned earlier (Orell-Füssli, 1933). We shall moreover follow, as far as possible, the same classification.

As in the 1932-33 work, the present article contains not only a description of the driving mechanism used on locomotives and railcars but also sets out, as far as possible, *the results obtained in service*. In addition, and according to the method of application, we shall show, at least in certain cases, the complete locomotive (or a dimensioned

sketch) from the point of view of running conditions (moving masses, wheelbases, load per axle, combined carrying and driving bogies, bissel trucks or guiding carrying bogies, etc.) in relation to the maximum speed which the engine should be able to achieve and in relation to the adhesion by comparison with the tractive effort to be developed.

This article is conceived in a purely practical sense, so as to give operators a survey of all the devices in use; no theoretical or mathematical principles are followed and reference may be made to the articles or works quoted in the notes at the bottom of the pages or in the bibliography.

Moreover, the work does not claim to be exhaustive; six years of war (1939/1945) and to some extent the post-war era have in fact made it very difficult sometimes to obtain the desired information.

Finally, so that this survey shall not be unduly long, reference will be made as far as possible to the work of 1932/33, which will be abbreviated in the text and in the notes to **Cde. indiv.**

Chapter 1.

GENERAL (1).

It can be said that, apart from locomotives and loco-tractors used for *shunting*, rod drive has disappeared. In fact, on locomotives used on *mountain* lines, and also on *goods* locomotives, it would seem that Administrations are abandoning rod-drive for electric traction (or Diesel-electric and other systems) in favour of individual axle drive only.

On shunting locomotives, for which — in view of their low speeds (65 km./h. — 40 miles p.h.) and their limited loads — a single motor is generally sufficient, it is more economical and also better for adhesion (high tractive effort in starting), to continue to use coupling rods (2).

It may be interesting to mention in passing an electric tractor particularly well suited for shunting in medium stations, which is used on a large scale by the Railways in Switzerland, principally the CFF. This is a loco-tractor, type B, class Te (see Fig. 1), series 61 (former series number 16001, cl. Ee2/2) with two rod-couples axles, one of which is driven by a motor suspended in tramway fashion, with gears (fig. 2) which can, owing to its simplicity of operation be worked by any member of the shunting staff, without requiring a specially-trained engine-driver. This type was manufactured in 1928 by the « Ateliers de Sécheron », of Geneva.

It can also be stated that, particularly in Switzerland, a large number of shunting engines are still being built with drive by rods from a single motor. Further, of the type designed by Brown-Boveri about the same time, and shewn in fig. 2 of **Cde. indiv.**, series 16331, type C (Ee3/3), 80 were already in service on the CFF by the end of 1943. The mechanical parts, running gear and bo-

(1) The general remarks on this subject, contained in the 1932/33 work, mentioned in the introduction, will not be repeated, but supplementary information only will be given.

(2) This case was similar to that of the three-phase locomotives (see **Cde. indiv.**, figs 3 to 5), one motor being too powerful for one axle and capable of driving at least two.

Sécheron — SLM.

Fig. 1. — Shunting tractor, Te class, Swiss Railways (single phase, 15 kV, 16 $^{2}/_{3}$ cycles).

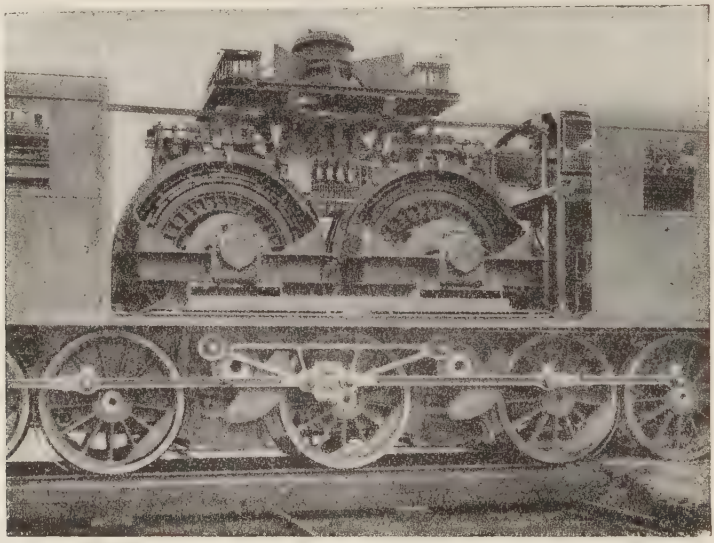
Sécheron.

Fig. 2. — Wheel arrangement, with motor, of the tractor shewn in Fig. 1.

dies of these locomotives were built by the Winterthur Locomotive Works (SLM), as indeed they are for all Swiss locomotives and many others.

In view of the disadvantages of drive through coupling rods, particularly at higher speeds, independent axle drive has even been tried on *steam locomotives.* Examples of this are : 1) the 2-C_0-2 locomotive of 3 300 H.P. for 140 km./h. (87 m.p.h.) built by the « Sociétés Alsaciennes, Fives-Lille et Schneider », to the design of SLM-Winterthur, and tested in the summer of 1939 with good results by the French National Railways (3); 2) the 25 000th locomotive of the Henschel Works, at Kassel, built for the Reichsbahn in 1941, which can reach a speed of 175 km./h. (109 m.p.h.) at which a power of 2 000 H.P. is developed.

The only recent cases of which the Author is aware, where rods have been used on electric passenger locomotives



Oerlikon — SLM.

Fig. 3. — 1-E-1 locomotive, series 151 (Be5/7), 1913, of the BLS (Bernese Alps) Railway, for maximum speeds of 75 km./h. (46 m. p.h.), 2 500 H.P., 2 motors. (See fig. 6 of **Cde. indiv.**)

are those where formerly rod-driven locomotives have been converted (modernised) in Switzerland during the second world war, with a view to increase power and speed (see figs. 3 to 6).

The subjects of figs. 3, 4 and 5 are notable both in execution and design (4).

Departing from the system of drive by

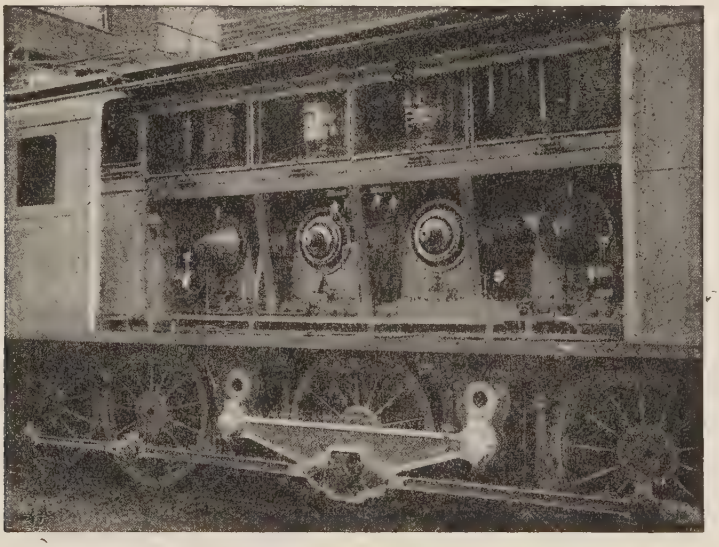
(3) *Revue Générale des Chemins de fer,* Sept./Oct., 1943, pp. 101/109, for comparison, on the other hand, with « Control Mechanism „Universal Drive" „SLM" », pp. 60/67 of **Cde. indiv.**

(4) See *Technische Mitteilungen SLM*-Winterthur, Dec. 1942, pp. 3/10. For fig. 6, see *Revue Brown-Boveri,* No. 10/11, 1945, p. 407.

a motor suspended tramway-fashion (5) (suspension from the nose, half the weight of the motor and the weight of the gears remaining unsupported other than on the axle) which will be dealt with further in Chapter II, all the mechanical systems allow the suspension of the complete motor as well as a part of the transmission.

It is known that the effect of unsuspended weight, particularly at speeds above 70 km./h. (43 m.p.h.), but also at lower speeds, is most unfavourable to the maintenance of rolling stock and permanent way, due to the hammer blow, particularly on rail joints (6) and also has the effect of increasing noise.

A much-discussed question is whether the cost, often much higher, of a flexible transmission with hollow shaft is justified, or if it is sufficient to provide elastic elements (generally coil springs) between the toothed rim and the body of the wheel (the pinion is generally too small for this (7) except in the case of large locomotives).



SLM — Oerlikon.

Fig. 4. — 1-E-1 locomotive No. 171 (converted in 1942 from No. 151, Fig. 3) of the BLS (Berne-Lötschberg-Simplon) Railway, single-phase current, 15 kV., 15, then $16\,^2/_3 \sim$, cycles, for maximum speeds of 90 km./h. (56 m.p.h.), 3 000 H.P., 4 motors (new designation Ae5/7). See Figs. 3 and 5.

(5) Also the « gearless » system, without hollow shaft, see **Cde. indiv.**, fig. 9, « Chicago, Milwaukee, St. Paul and Pacific Railroad », 1919. The introduction in this case is entirely unsuspended.

(6) See **Cde. indiv.**, fig. 21, and following explanation (p. 14).

(7) See fig. 7 — typical example of this kind.

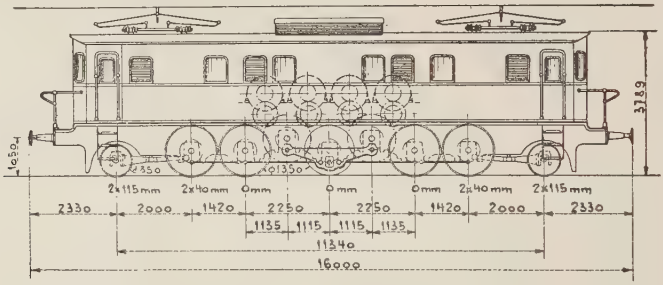
The Author's opinion is that in almost every case, including secondary railways and tramways, the provision of an elastic transmission, allowing the complete suspension of the motor, is justified.

The provision mentioned above, of elastic joints between the toothed rim and the body of the gear wheel provides a fairly satisfactory compromise. Fig. 7 shows a series of gears as fitted in 1941 to electric locomotives of the Swiss SOB (South-Eastern) Railway and other Administrations. This is one of the most interesting of the arrangements provided in a case where it was considered that a transmission gear with hollow shaft would not be justified on account of the cost (8).

It can also be stated, as a further general remark on the question of gears, that the almost universal experience, having regard on the one hand to maintenance costs, and on the other hand to the noise, proves clearly that all traction gears (transmission of motive power by gear and pinion or double reduction) must in every case have the teeth *tempered* and *normalised*. The additional cost resulting from the use of such improved gears is largely compensated by a reduction of the operating costs and by the excellent behaviour and strength of the transmission.

Amongst the works which may be consulted on the theoretical consideration of transmission systems is « Cours de Traction Electrique » (Ecole Supérieure d'Electricité, Paris), pp. 79 to 99, by H. PARODI (1936-7). An interesting division into classes will be found therein.

To conclude these general remarks a few words may be said on the subject of adhesion. A slipping of one or more axles may arise either when *starting up*, according to local or prevailing conditions on the track and the tractive effort to be developed in relation to the adhesive weight, either when *running* at high speed owing to local conditions or arising from the coupling of the motors



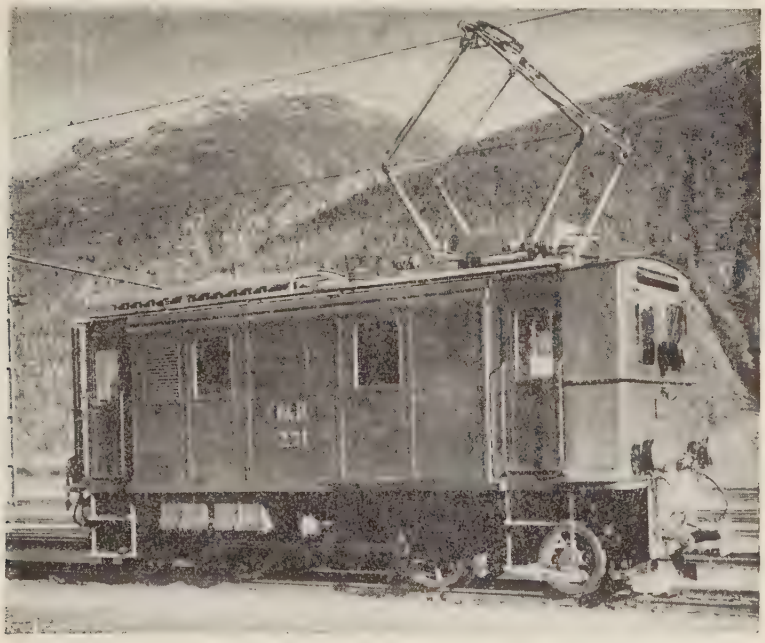
SLM.

Fig. 5. — Dimensioned sketch of the BLS locomotive shewn in Fig. 4 (double reduction gearing, high-speed motors). See Fig. 4 and Fig. 6 of **Cde. indiv.**

(8) See *Economie et Technique des Transports*, 1942/3 volume, pp. 3 and 19/20 (Protex-Maag gears for Swiss SOB motors), and *Spoor- en Tramwegen*, The Hague/Utrecht, No. dated 1/7/44, pp. 163/165.

(series or parallel); finally, on occasions it may arise owing to mishandling by the driver. As a result of the improvements in transmission systems and progress in construction, the conditions of adhesion in general seem rather to have improved (9). Often, compensation is derived from the fact that the slipping axle, taking less energy from the motor, builds up the drive on the other axles, which may cause them in turn to slip, giving rise to an interchange, generally of short duration.

To obviate the occasional slipping at high speeds, a coupling has been designed to link the control gears of two neigh-



BBC — SLM.

Fig. 6. — 1-B-1 locomotive No. 221 (and 222) of the Swiss Rhetique Railway, single-phase, 11 kV., 16 $^{2}/_{3}$ cycles, converted from 201 series engines of 1913; Deri motor replaced by series motor of high speed with double reduction by gears.

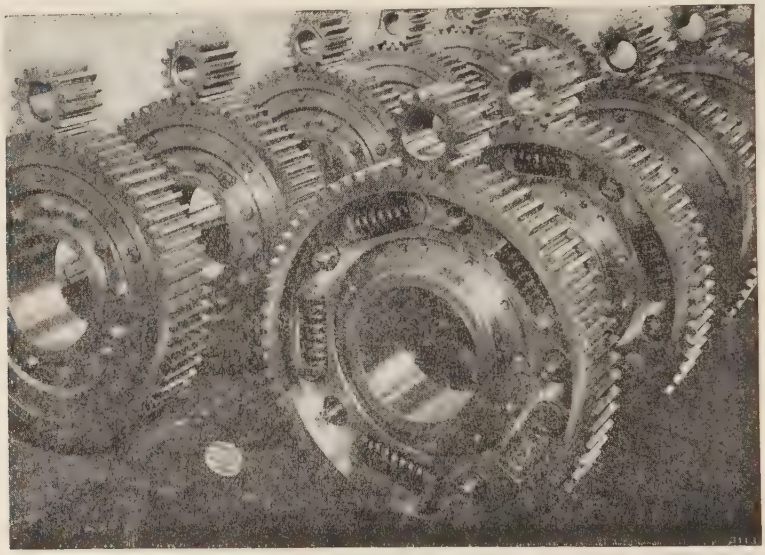
Comparative table.

	1911	*1945*
Nos. of locomotives	ser. 201	221-222
Hourly rating, H.P. (at motor shaft)	310	612
at a speed of km./h.	28	39
Maximum speed, m.p.h.	28	40
Tare, Engl. tons	36.415	31.494

(9) As in the case of the 2-D-2 locomotives, Nos. 5302-5306 of the SNCF (SW region), dealt with later.

bouring driving axles by means of an intermediate gear wheel (9). This may be justified in certain cases and so provides the advantages given by rod coupling without the maintenance disadvantages.

the springs should be as resilient as possible, and non-binding, and secondly, that between the transmission and the rail the weight should be low by comparison with that between the motor and the drawbar. In many cases, however,



Maag.

Fig. 7. — Series of gears with spring-loaded toothed rims, Protex-Maag type, for electric railcars of the Swiss SOB (South Eastern) Railway, 1940.

In his work « Über die Adhäsion federnder Lokomotiv-Einzelachsantriebe » *(Adhesion of locomotives with individual axle quill drive)* (10), Dr. LENK, the Viennese engineer, decided by theoretical calculations that to obtain good alhesive conditions it was necessary firstly that practical results differ from theoretical considerations which have only a relative value.

On the subject of gearless drive (11) there is nothing to add to what has already been said, the system apparently no longer being fitted.

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(9) As in the case of the 2-D-2 locomotives, Nos. 5302-5306 of the SNCF (SW region), dealt with later.

(10) See July, 1930, edition of *Elektrische Bahnen.*

(11) See Chapter II, pp. 7-11 of **Cde. indiv.**

Chapter II.

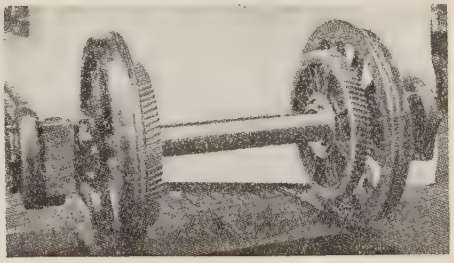
DRIVE BY MOTORS SUSPENDED FROM THE NOSE (TRAMWAY FASHION).

In this Chapter, too, there is not a great deal to add to what has already been said [12]. The question of the improvement which may be obtained by inserting springs in the gear [13] has already been dealt with, and what has been said in the General Remarks covers the modernisation of this system; it is important that the springs should have sufficient initial compression.

It should be noted that certain systems which experienced numerous breakages of teeth in the beginning, no longer suffered from this defect when elastic elements were introduced into the toothed rim. As the pinion is generally small in motors suspended by the nose, the elastic elements are fitted in the large gear wheel, as indicated in Chapter I (General) [14].

Several arrangements are, however, worthy of mention in their particular application; one being the large number of B_0B_0 locomotives of the SNCF (see further) and another, the B_0B_0 locomotives for local and light goods trains of the German Reichsbahn, type E.44. Twenty-four of these engines were built in 1932/3 [15] for a maximum operating speed of 80 km./h. (50 m.p.h.). This was then, the Author believes, the highest permissible speed for this type of engine.

The motors of the E.44 engines are suspended from the nose, of normal construction without spring elements, but with gears having oblique teeth (fig. 8). The tare of the engines is 77.2 tons (75.979 Engl. tons) and the axle load is consequently around 19.5 tons (19.19 Engl. tons). The hourly rating at 73 km./h. (45 m.p.h.) is 2 900 H.P. The two coupled bogies have a wheelbase of 3.5 metres ($11'5^{13}/_{16}''$).



SSW.

Fig. 8. — Driving axle fitted with double-sided gears with oblique teeth and Isothermos axleboxes, B_0+B_0 locomotives, class E 44, German *Reichsbahn*.

As a main point of this Chapter, mention must be made of the results obtained with the B_0B_0 locomotives of the P-O section (W and SW Regions) of the SNCF, used on a large scale since about 1925 and built by Oerlikon (electrical equipment) and afterwards by other

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[12] See Chapter III, pp. 11-21 of **Cde. indiv.**, *also* « Zur Mechanik des Tatzenmotors », K. Pflanz, *Elektrische Bahnen*, Feb. 1941, p. 31.

[13] See figs. 17 and 24-27 of **Cde. indiv.**, pp. 15-16.

[14] See fig. 7 and notes [7] and [8] at bottom of page.

[15] 20 for the Augsburg-Stuttgart line and 4 for the Freilassing-Reichenhall-Berchtesgaden line — see *Elektrische Bahnen*, July, 1933.

firms in France. The first series comprised 200 locomotives of an hourly rating of 1 600 H.P. and they were first designed for a speed not exceeding 65 km./h. (40 m.p.h.) (local and goods services, multiple hauling, see fig. 9).

At the end of 1943, the SNCF possessed a total of 600 B_0+B_0 type locomotives, of which certain series were built (or converted) for speeds up to 90 and even 105 km./h. (56 and 65 m.p.h.).

Series 011 to 040 locomotives, for speeds up to 90 km./h. with gears on one side (two-part gears, assembled with bolts) were first used for suburban passenger services; when they were used for goods services there was a marked tendency to wear on the teeth of the gears. Series 101 locomotives (speeds up to 95 km./h. [59 m.p.h.]) with rigid gearing and monobloc gear wheels showed, as also did those with gears on both sides, a general tendency to wear owing to the absence of sprung teeth. About sixty engines of this series, those with one-side gears, have gear wheels of 80 kgr. (176 lb.) carbon steel for the gear rims and CrNi, 105 kgr. (231 lb.) steel, hardened and tempered for the pinions, lubricated in a compound gear case. Their behaviour has been satisfactory. The suspension of the motors of the locomotives with double-sided gears is stated to be very satisfactory since the fittings of springs, a solution which seems to have a most favourable effect on the axle cushion blocks of the driving motors.

Oerlikon.

Fig. 9. E.103 locomotive, type B_0+B_0, 1926, Paris-Orleans (SNCF), with 1 000 tons goods train.

Locomotives Nos. 1 to 80 (speed up to 90 km./h.) are fitted with rigid single-sided gearing (monobloc gear wheels) and motors supported by the nose on a group of helical springs (Pennsylvania sleeves); the gears (as for the series mentioned above, carbon steel 90 kgr. [198 lb.], and CrNi 105 kgr.) have shewn a marked tendency to wear, and breakages of bolts in the motor suspension have been experienced.

All these series of locomotives are given a general overhaul after a mileage of 135 000 to 140 000 km. (83 885 to

86 992 miles). Series 201-224 (speed up to 70 km./h. [43 m.p.h.]) used largely for shunting, are overhauled every 100 000 km. (62 137 miles).

Other series show similar results.

Engines 165-180 and other series (speeds up to 105 km./h. and up to 70 km./h. respectively) with single sided gears but with spring-loaded gear wheels (mounted on the axle, alongside the driving wheel) shew defects due to the two-piece rim of the sprung gear wheel; these defects, mostly broken teeth, have been overcome by the use of a new wheel with monobloc rim.

In general it can be said that there does not seem to be any appreciable difference in behaviour between single and double sided gear systems. On the other hand, maintenance costs are noticeably lower when using elastic rims. In cost, either first-cost or maintenance, flexible toothed rims are cheaper than double-sided rigid gears.

An important matter still to be considered in this Chapter is that of axle fractures, generally arising between the hub of the wheel and the gear wheel. It is always necessary to have the axle diameter rather greater where the centres (wheel and gear wheel) have to be pressed on. In every way the risks are reduced by the use of flexible toothed rims in cases where a fully slung motor with flexible drive (if necessary with a hollow or partly-hollow shaft) is not considered preferable.

Within the scope of this Chapter the question of *adhesion* can be raised again, being a very important point in the case of bogies with two nose-suspended motors. Reference may be made to the remarks in Chapter I, General, pages 829 and 830.

The problem is dealt with in an interesting and complete manner in the work already mentioned on page 828, Chapter I [16].

It is known that in operating practice on railways and tramways the adhesion factor is *very* elastic and depends on all manner of conditions, permanent or temporary, local or constructional, and the factors generally allowed — according to the type of engine, the method of haulage and the track conditions — have always had a very generous safety margin, which is logical since it is necessary in principal to take the most unfavourable conditions.

It is also known that adhesion is a little lower with engines of B_0B_0 type; under the tractive effort, particularly in starting, the front axle has a tendency to lift, consequent upon the fulcrum effect of the pivot of the bogie, which causes the leading axle to race. To meet this, in addition to the use of a device for compensation of load by pneumatic pressure on the front headstock of the bogie, it is possible to fit an electro-pneumatic valve, operated when necessary by the driver, providing a brief and moderate brake effort to the axle which tends to race [17].

The publication mentioned [16] shows, amongst other things, by the use of the figures at the top of page 24, the relative percentage of adhesion, that is to say, the variations in the adhesive factor in

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[16] See p. 21 and following (particularly p. 24) of « Conférences sur la Traction Electrique », H Parodi, 1936/7, Vol. 1.

[17] See pp. 340-341 of Vol. 10/11 of 1945 (special electric and thermo-electric traction number) *Revue Brown-Boveri.*

relation to the position of the motors (and their suspension) compared with the axles and the symmetrical centre of the bogie. It is shewn that the asymmetrical position of the motors in relation to the bogie pivot can noticeably increase the adhesion, as can the suspension of the axles and their connections, apart from the connections between the

21, with 22 figures) and have seen that in general there is nothing new to add. In fact motors with nose-suspension (with or without flexible elements in the toothed rims of the gear wheels) are still almost universally used for urban and suburban train sets.

They are also still used very often for diesel-electric sets, and sometimes even

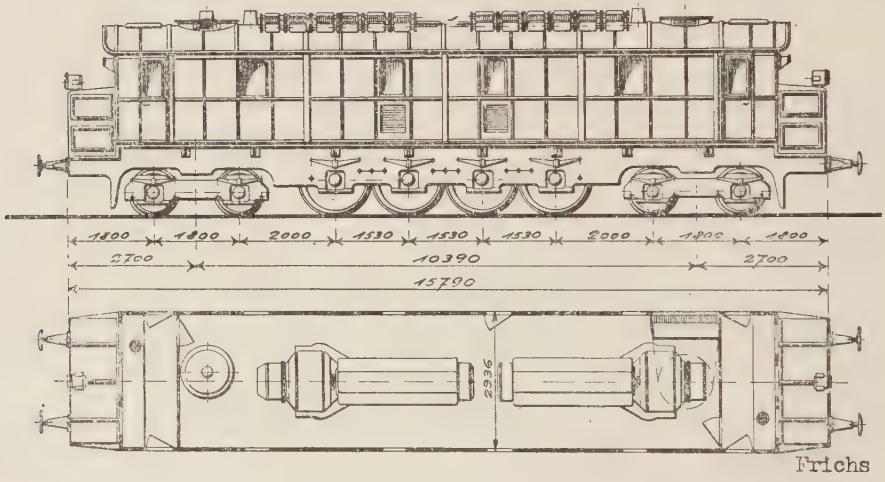


Fig. 10. — Diesel-electric locomotive of the DSB (Denmark), 1931.

Weight in running order (adhesive)	102 (51.7) t. (100.38 [50.88] Engl. t.)
Max. power of each of the two Diesel motors	500 H.P.
Diameter of driving wheels (carrying)	1 404 (934) mm. ($4'7^{7}/_{32}''$ [$3'^{25}/_{32}''$])
Maximum speed	110 km./h. (68 m.p.h.)
Rigid wheelbase (driving axles)	4 590 mm. ($14'9^{3}/_{16}''$)

bogies. However, constructive and practical considerations are of more value than theoretical ones.

It seems important at this point to form some conclusion to this Chapter II regarding motors with tramway suspension.

In this Chapter we have not gone into the same details as in Cde. indiv. (pp. 11-

for diesel-driven large locomotives. Examples which may be quoted are the two diesel-electric locomotives Nos. 131 and 132, type 2-D_0-2 of 1 000 H.P. hourly rating, for maximum working speeds of 110 km./h. (68 m.p.h.) supplied in 1931 to « Danske Statsbaner » DSB (Danish Railways) by the Frichs works, Aarhus (fig. 10). These engines each have four

driving axles, as have all railcar sets of the DSB ([18]), one motor suspended from the nose with single gear reduction; the maximum load per axle is, it is true, only 13 tons and the construction dates from 1929/30.

The large American diesel locomotives, notably those of the *Union Pacific*, designed for express service between Chicago and San Francisco and put into service before 1939 (of which an example is the « City of Los Angeles » series LA-5) are also, it is understood, fitted with nose-suspended motors. On the other hand, the large diesel-electric locomotives put into service in Europe during the last ten years, particularly by the SNCF (S-E region, PLM line) and by the Rumanian CFR (Căile Ferate Române) on the Campina-Brasov mountain line, have been provided with flexible transmission gear, and will be dealt with in the appropriate chapters.

We may also note the cases of locomotives with transformers. These are already rather complicated, having generally been equipped with motors hung by the nose, and moreover have been experimental. As examples, there are firstly, the already old $1D_01+1D_01$ with rotary converters, of the American Great Northern system, for heavy goods trains (hourly rating 4 400 H.P. tractive effort 51 t. [50.19 Engl. t.] at 23 km./h. [14 m. p.h.], maximum speed 72 km./h. [45 m. p.h.], total weight 337 tons [331.67 Engl. tons], equivalent to 76 kgr./ch. [170 lb./H.P.] developed by the Westinghouse Electric and Manufacturing Co.) ([19]) and secondly, the two engines with mercury vapour rectifiers, type B_0+B_0 of the German Reichsbahn which were built, one by Brown-Boveri and the other by AEG. These were built in connection with the test of a tension of 20 000 V., single-phase, 50 cycles, for the Höllenthal line (power 3 000 H.P. weight 84 tons [82.673 Engl. t.]) ([20]).

Finally for the same Höllenthal line, the Siemens-Schuckert works built in 1934-36 the B_0+B_0 locomotive series 244, No. 21, for the Reichsbahn, which was put into service in June, 1936, operated directly at 50 cycles ([21]). As the single-phased motors, in view of the frequency, could only be built for a low tension, it was necessary to fit two per axle, permanently connected in series. In this case 14-pole motors were used, for which the speed of the commutator was 53 m./sec. (174 ft./sec.) at the maximum operating speed of the engine of 85 km./h. (53 m.p.h.); the 14 brush-holders had to be placed in two staggered series (rings) of seven each. Figures 11 and 12 shew these traction motors.

Experience gained in numerous cases shews, however, that it is preferable to suspend the motor entirely, or at least to provide gearing (as already shewn in the first Chapter, see also Fig. 7) with a well-sprung toothed rim. The best solution is to fit both arrangements together. The injurious effect of hammer blow on the track by the unsprung mass obviously depends on the rail section (weight per running yard), on the track superstructure, on the total axle load and

([18]) See *Bulletin SBB-CFF*, Berne, Feb. 1937, p. 24 (fig. 1-3); « Zugförderung mit Diesel-Fahrzeugen in Dänemark » (Train working with Diesel sets in Denmark) (German and French).

([19]) See *Elektrische Bahnen*, Berlin, special supplement for 1936, pp. 71/72, fig. 35.

([20]) Idem, pp. 75/76, figs. 41/42.

([21]) See *Elektrische Bahnen*, Berlin, March/April, 1937.

on the running speed. Equally, the robustness of the motor construction and the bogies is involved, which implies a certain supplementary weight. However,

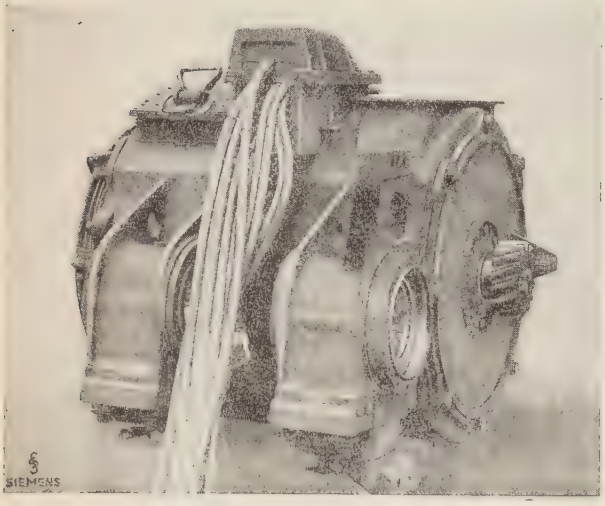


Fig. 11. — Traction motor, single-phase, 50 cycles, nose-suspension, for two-point mounting on axle (see Fig. 12). The very small pinion can be seen, 15 teeth only, cut obliquely at 20° (reduction 1 : 5.87). The blocks resting on the axle are separated, those of the second motor bearing alternately along the axle. Weight of motor without gears, 2.5 tons (2.46 Engl. t.), hourly rating 330 H.P.

the modern tendency in the construction of rolling stock — actually with a view to economy in operation — is towards *lighter* stock. Here is another reason, in reducing the maintenance costs of motors, gears, bogies and railcar sets in general, for reducing to a minimum the impact of the moving masses, as well as the vertical and transversal shocks transmitted to the rail.

It could consequently be asked whether, with technical progress in construction on the one hand, and the requirements of operation on the other, the nose-suspension of motors should not disappear. Its suppression is naturally a question of cost, of weight, of impeding and complicating construction, but it is thought that in spite of all these circumstances the complete suspension of motor is justified. There are now new flexible transmission systems, much improved over the old ones, which will be described more fully, as regards railcars, in Chapters IV and VI. As will be seen, moreover, in Chapter VII, even for tramways, where the axle load is low and the rails entirely welded, the most recent large-scale experience demonstrates the advantage of fully-suspended motors with very flexible transmission, the question mentioned above of cost, weight,

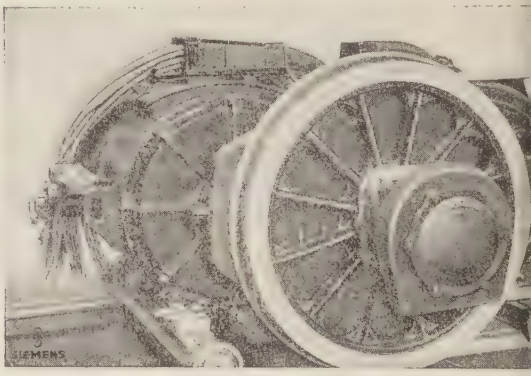


Fig. 12. — Driving axle of E 244.21 locomotive, Reichsbahn DR (2 700 H.P. hourly rating), two carried on the axle, nose-suspension, double-side (the two roller beams seen to right and left wheel set are not part of the arrangement, servi to hold the motors in position for the photogr

complication and hindrance being solved and economically compensated by the great reduction in maintenance of rolling stock, motors and track.

(To be continued.)

[621 .133 .1]

The oil firing of steam locomotives.

A survey of the present position in certain European and Overseas countries,

by F. STRAUSS, London.

I. Introduction.

Oil-fired steam locomotives are nothing new. The country where this system of firing of steam locomotives was tried out at first was Russia, which in 1884 had about 100 steam locomotives fitted for burning petroleum refuse. Since then, the numbers of oil-fired steam locomotives increased considerably, but, unfortunately, details giving the extent to which they are used and the type of oil-burning equipment fitted are at present not available.

In Great Britain, the former Great Eastern Railway had its first oil-fired locomotive in operation in 1893. This locomotive was built by James Holden and appropriately named « Petrolea ». The reason for the experiment then was that the Great Eastern passenger rolling stock was lighted by oil gas, and difficulty arose with the disposal of oil waste into normal sewage channels; hence, it was decided to endeavour to dispose of it as locomotive fuel. In all, about 60 locomotives were equipped for oil-firing on the Great Eastern Railway at that time. As soon as oil fuel had to be purchased from outside sources the price rose; with the extended adoption of electric carriage lighting, the company's own supply of oil waste dropped and thus the oil-burning steam locomotives were converted into coal burners.

In the United States and other oil producing countries oil-fired steam locomotives are widely used; only the advent of the diesel-electric locomotive checked the extension of their use in the United States. As early as 1896, half of the locomotive stock of the Atchison, Topeka and Santa Fé Railway in Southern California had been converted from coal to oil-burning. This railway is still one of the largest users of oil-fired steam locomotives in the world.

In 1943 there were on Class I railways of the United States 39 700 steam locomotives of which 6 700 or 16.8 per cent. were oil-fired. The quantity of fuel consumed by oil-fired steam locomotives in 1945 was 17 000 000 tons of fuel oil compared with 124 000 000 tons of coal consumed by coal-burning locomotives. These figures represent 14 per cent of the fuel oil and 20 per cent of the coal production in the United States during that year.

In countries without indigenous oil resources, oil-fired steam locomotives are only used when locomotive coal is either unobtainable or in short supply. Even then they are never used extensively or for lengthy periods, as they are not regarded as an economical proposition but only as an unavoidable stop gap. Moreover, it is evident that strategic considerations are against the use of oil as loco-

motive fuel in countries which produce only very little or no oil at all, but which have either coal or water power resources available for traction purposes.

Before dealing with the equipment used on, and the state of development of, oil-fired steam locomotives in certain European and Overseas countries, one important factor which may be decisive for the future of this type of steam traction, has to be mentioned, namely : oil fired in steam locomotives can never produce results comparable to those of its use in diesel locomotives, the reason being that the thermal efficiency of a diesel locomotive is about three to four times higher than that of a steam locomotive of the same H.P. output.

It results therefrom that, when a country without indigenous oil resources considers as a long-term policy to run its railways on imported oil fuel, then the oil should undoubtedly be used in prime movers in which its consumption is lowest and its thermal efficiency highest, i.e. in diesel locomotives.

II. Equipment used on oil-fired steam locomotives.

The equipment used on oil-fired steam locomotives can be classified into several groups, according to the type and position of the burner. Although there are thousands of patents for oil burners — up to 1st November 1939 no less than 1 975 patents for oil burners had been taken out in the United States alone — the principle on which modern oil burners work is always the same, i.e. steam is used to atomize the oil.

There is, however, a marked difference in the method of using the oil burners. On the railways in the United States, Belgium, France, Great Britain, Italy, the Middle East and certain South American countries where oil-fired steam locomotives are in operation, single oil burners are used. On the other hand, certain Central European railways as well as some Overseas railways which use oil-fired steam locomotives, consider it more advantageous to have two oil burners per locomotive and *to fire a mixture of fuel oil and low-grade coal.*

As a detailed description of the various types of oil-burning equipment in use would exceed the scope of this article, only two types, which are commonly used, will be dealt with here namely :

(*a*) The « American-type » equipment used by the Great Western Railway of Great Britain for firing fuel oil alone, and

(*b*) The Hardy equipment used by Central European railways for firing a mixture of fuel oil and low-grade coal.

(a) The equipment used by the Great Western Railway (*).

This oil burning equipment which is very similar to that generally used on U.S. railways consists essentially of one weir-type burner, an oil regulating cock, a steam manifold carrying the necessary control-valves and a pre-heater on the engine, while the tender equipment comprises fuel oil tanks, heating coils in the fuel oil tanks, a drainage valve, an oil filter, a shut-off cock and finally flexible oil and steam connnections between tender and engine *(see Fig. 1).*

Description of equipment.

Fuel oil is contained in a tank having a total capacity of 1 800 gallons and design-

(*) See *The Railway Gazette* (18th January, 16th and 30th August 1946) and *Modern Transport* (16th November 1946).

ed to fit into the coal space of the 3 500 gallon well-bottom tender. The front of the tank is lagged with asbestos non-conducting composition; precautions have been taken to prevent free circulation of air around the sides and back. An oil filler pipe of 4 in. bore runs from the top of the oil tank towards the rear, and then passes vertically downwards, and from which it is drawn through a stand pipe 1 ft. 5 in. high. This chamber contains two steam-heating coils with a total heating surface of 29.5 sq. ft. It is also fitted with the bulb of a Rototherm thermometer, the dial of which is carried on the front of the tank. Auxiliary heating loops, each with a heating surface of 8.5 sq. ft. are fitted one on

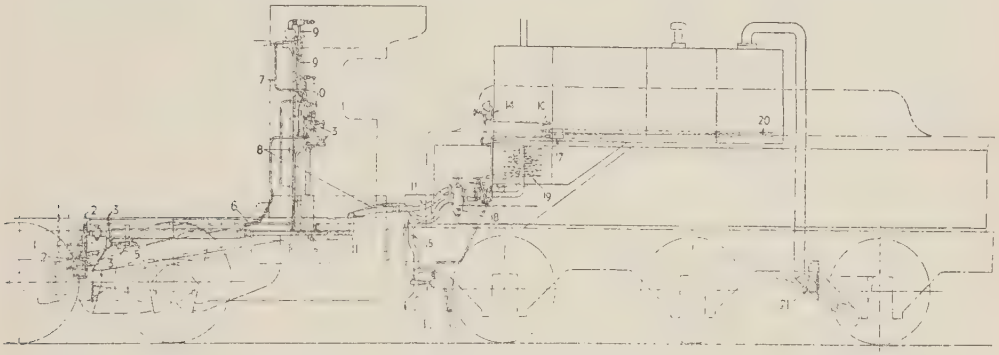


Fig. 1. — Layout of fuel tanks and oil fuel firing apparatus on a Great Western Railway 2-8-0 locomotive.

Reference.

1) Oil regulator cock to burner.
2) Steam to cleaner.
3) Steam to burner.
4) Drain from heater (engine).
5) Connection from strainer to trap (engine).
6) Steam to heater (engine).
7) Steam from auxiliary blower.
8) Heater steam from engine manifold.
9) Steam fountain to manifold.
10) Steam from Masons valve.
11) Oil fuel to engine heater.
12) Connection from strainer to trap (tender).
13) Drains from steam trap (tender).
14) Heater steam to tender manifold.
15) Drain from sludge cock.
16) Steam from tender manifold to heater.
17) Steam from tender heater to strainer.
18) 1½-inch. Auto-Klean strainer.
19) Steam-heating coils.
20) Steam-heating coils along tender sides.
21) Oil fuel filler.

through the water space to the underside of the water tank, where it branches transversely to provide a filling point on each side of the tender. The oil level is indicated by a flat gear of conventional type.

The lower front portion of the tank is a partly-sealed chamber about 3 ft. 6 in. × 2 ft. 4 in. deep into which the oil flows through holes in the back partition plate, each side of the main tank. The steam supply to the heating coils is controlled by three valves mounted at the front of the tank on a manifold which is fed through a flexible hose from the steam manifold on the engine.

The oil from the stand pipe passes through a 2 in. shut-off cock and a filter and thence through a flexible hose to a 1.5 in. bore pipe running under the left-

hand footplate of the engine. Here it passes through the pre-heater in the form of a steam jacket about 5 ft. 3 in. long and then immediately through the oil regulating cock to the burner.

The oil regulating cock is linked to a quadrant graduated in degrees and operated through a pinion drive by means of an horizontal control wheel located in the front left-hand corner of the cab.

The steam manifold on the engine, situated immediately to the right of the oil control wheel, is fed with saturated steam from the boiler fountain, and carries five valves controlling steam to :

(1) the burner;

(2) the burner cleaner;

(3) the ordinary blower in the smokebox;

(4) the oil pre-heater on the engine; and

(5) the oil heater on the tender.

A sixth valve on the manifold enables steam from an outside source to be made available at all these points during lighting-up. The steam supply from the manifold to the blower is tapped into the body of the normal blower valve. By this arrangement steam from the auxiliary supply can be fed to the blower while raising steam, and, in addition, the location of the special blower valve close to the other oil-burning controls enables the fireman to operate the blower as required.

The burner, mounted at foundation-ring level in a small chamber at the front of the firebox, is of the type in which oil flows over a weir on to a ribbon of steam by which it is caught up, atomized and projected towards the back of the firebox at an inclination to the horizontal. The oil orifice is 2 in. wide $\times$ $\frac{1}{2}$ in. deep and the steam orifice immediately underneath is $2\frac{1}{2}$ in. wide $\times$ 0.018 in. deep. The chamber carrying the burner has a small bottom damper door which can be pre-set to a suitable opening.

The floor of the firebox consists of a steel plate in which are cut six rectangular holes giving a total air inlet of 2.25 sq. ft. The normal type of ashpan has been modified to provide a suitable firepan; the original damper gear is retained. The air supply to the firebox through the orifices in the floor is controlled by opening or closing the damper doors in the firepan. Firebricks with a high alumina content are used to line the floor and the lower part of the firebox; a standard brick arch is fitted.

The firedoor has been re-designed to form a reasonably effective seal, and although easily opened, is effectively locked when in the shut position. An inspection hole with cover is also provided.

The normal spark plates have been removed from the smokebox and the blast pipe orifice had to be altered in order to give the best draught conditions.

Lighting-up.

When lighting-up the engine the boiler steam valve on the fountain has to be closed and the external steam supply coupled to the engine. At motive power depots this is usually derived from the boiler washing steam main. At sheds without boiler washing steam main equipment, the steam required for starting up may be obtained from another locomotive; special adaptors are provided for taking it off from the injectors for boiler washing in such circumstances, while another type of adaptor enables the steam to be obtained from the steam heating pipe on the engine. Steam is then turned to the manifold, from which the tender heating coils can be supplied

by opening the appropriate cocks on the tender. These are partially closed down, with the side coils shut off altogether, when the temperature in the tender tank approaches 160 degrees Fahr. Lighting-up can, however, be performed as soon as the tender Rototherm shows more than 100 degrees Fahr.

When the time for lighting-up comes, the front and back dampers should be half open, the oil feed cock on the tender must be open and the filter handle given a few turns back and forth. The blower must then be put on slightly and, if necessary, the steam jets of the burner cleaner valves have to be operated; obviously these must be closed down before lighting-up. Burning scrap cotton waste saturated with oil is then inserted on a special rod through the firedoor inspection hole and the burner steam valve opened to show at least 10 lbs./sq. in. pressure. The fireman's oil regulating cock is then opened. The oil should light on emerging and should be eased back to the smallest possible steady flame. As the valve does not open until the quadrant has been turned about 20 deg. a stop is provided to prevent the fireman accidentally shutting off the supply when running with the minimum flame. The auxiliary steam should be shut off when a pressure of 70-80 lbs./sq. in. is obtained.

When the fire is first started up and the brick work is cold, only a light fire should be maintained, but later, as the brickwork becomes heated the fire may be increased as desired. It is necessary to see that the entire oil passing through the burner is being consumed in the firebox and that none of it is dripping down into the pit or on the ground under the locomotive. An accumulation of oil under the firebox is liable to catch fire.

To avoid damage to stays and tubes lighting-up from cold takes about the same time — 2½ to 4 hours — as with coal-fired locomotives. On the other hand, if the steam pressure of an engine is about 160 lbs./sq. in. it takes only 15 minutes to raise it to 225 lbs./sq. in.

Closing-down fire.

Shutting-off of the oil fire involves the closing of the shut-off cock on the tender, and after the connecting pipe has had time to drain off, the oil regulating cock on the engine. The steam to the blower and burner is closed down and the manifold is shut off by closing the supply to steam fountain.

Maintenance.

As the oil-burning equipment on the Great Western Railway has only been in use for a comparatively short period and on a relatively small number of engines, (37), at present it is not possible to give any reliable data on the maintenance of the firebox and boiler. Oil-fired locomotives are given a weekly inspection with the firehole door removed at boiler washing and stay inspection periods. It takes only 20 minutes to dismantle and replace the firehole door while the additional examination of the brickwork occupies only a few minutes. Any carbon deposit around the tip of the burner has to be scraped off by the fitter and the burner examined while the engine is on the shed. So far, little firebrick trouble has been experienced.

The firehole door protector castings — of cast iron, about 2 in. thick — as well as the firehole rings may need to be changed frequently.

A factor which may influence boiler repairs ultimately, is the absence of a sanding device for tube cleaning as generally used on American oil-fired steam locomotives (see pages 861-862).

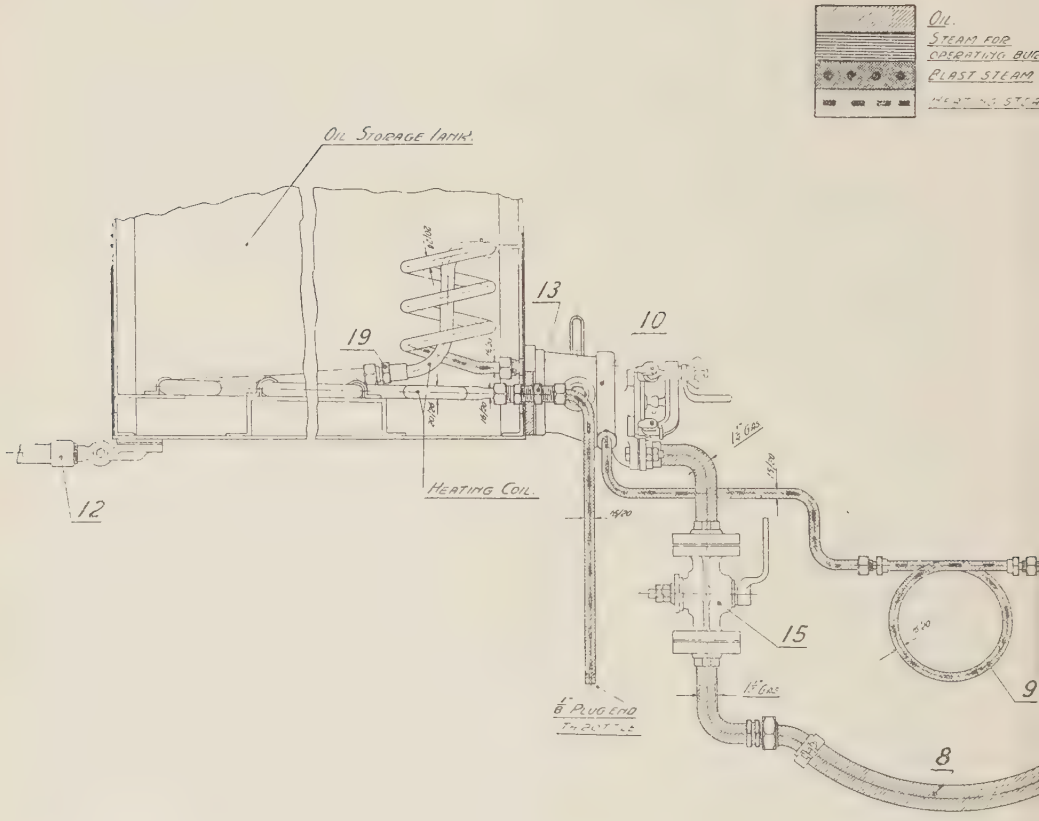


Fig. 2. —

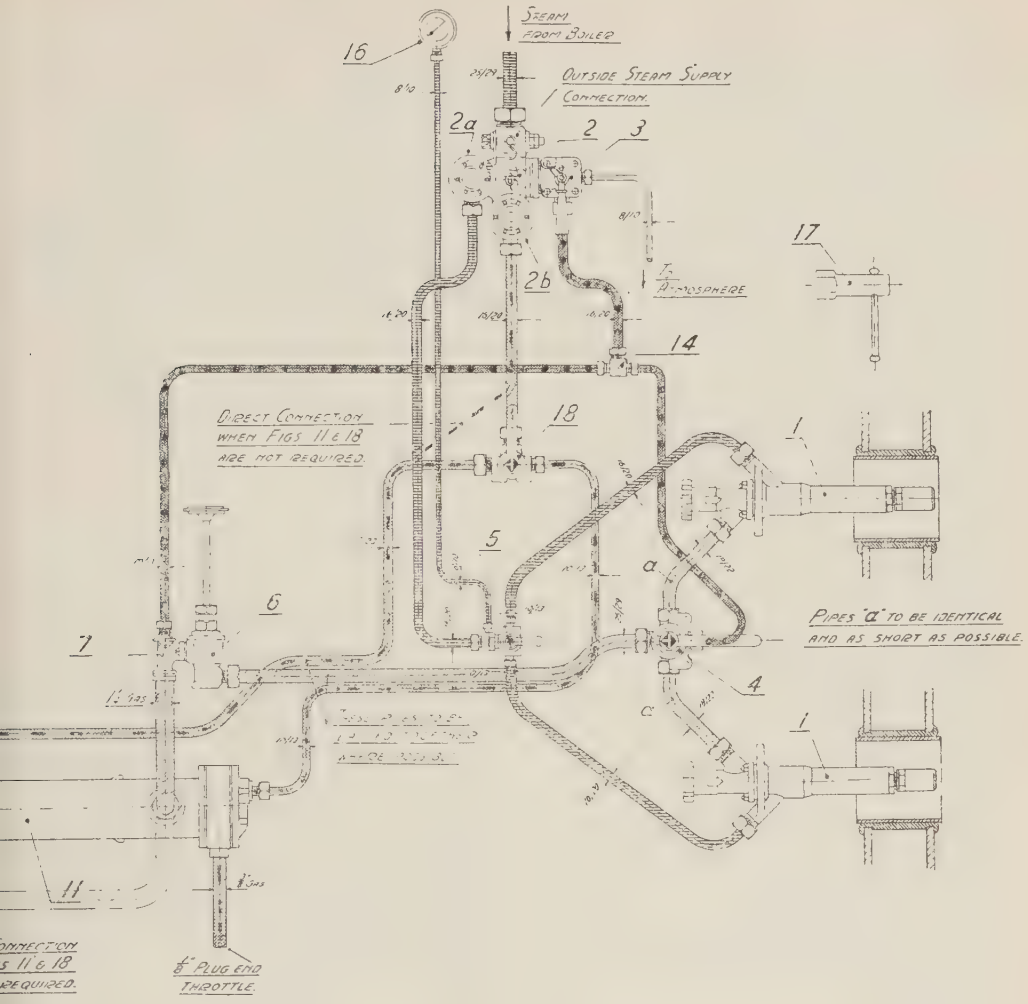
1) Burners.
2) Combined steam application valves.
3) Disc valve for blast steam.
4) 3 way cock for oil pipes.
5) 3 way cock for steam pipes.
6) Oil regulating valve.
7) T-elbow and plug cock.
8) Hose coupling-oil pipe.
9) Steam pipe coupling.
10) Shut-off valve with filte

(b) The equipment used on certain Central European Railways.

The Hardy oil-burning equipment consists in the main of :

(1) A steam manifold with pressure gauge — for the supply of steam to the burners, the pre-heater on the engine, the heating coils on the tender and for blowing through of the pipes and burners.

(2) A three-way cock for shutting-off



rrangement.

)il preheater.
)rain valve.
Connections.
C-connection for blast steam.
Shut-off valve for oil-pipe.

16) Gauge.
17) Box key for burners.
18) 3 way cock for oil pre-heating.
19) Connection for heater coils.

the steam supply to the burners or for shutting-off alternate burners.

(3) A three-way cock for shutting-off the oil supply to the burners or for shutting-off alternate burners.

(4) Two burners, symmetrically arranged at the sides of the firedoor.

(5) An oil supply control valve.

(6) A steam-operated pre-heater on the engine.

(7) Flexible oil and steam connections between engine and tender.

(8) An oil strainer and shut-off valve.

(9) A drainage valve.

(10) Steam operated heating coils in the fuel oil tank.

Space does not permit of describing the technical details of the single parts listed above. They are, with the exception of the burners, similar in principle to the equipment installed by the Great Western Railway and described under (*a*) above.

The main feature of this equipment is, however, its twin burners and the fact that it is mostly used in conjunction with a thinly spread coal fire. (*Fig. 2* gives the general arrangement of the equipment.)

The quantity of coal used is very small as the depth of the firebed need only be 8-10 in. The replenishing of the coal-bed is easy and can be done when the burners are «on» or «off» as they spray towards the tube plate and not towards the cab.

The advantages and disadvantages of firing a mixture of fuel oil and low-grade coal as compared with straight oil-firing are set out below :

(A) Operational advantages.

Lighting-up.

(1) The kindling of the oil burners is facilitated considerably and is not dangerous as the coal fire ignites the oil automatically.

(2) No danger of oil running into pits or elsewhere while engine is stabled at the shed, should oil flame go out during lighting-up process.

(3) Engine can be moved by its own steam in shed area.

On the other hand, an oil-fired locomotive without a coal fire which has its burner turned low, while being on the shed, should not, according to the current American instructions, be moved under its own steam without first increasing the flow of oil to the burner by the amount necessary to prevent the strong draught created by the exhaust from extinguishing the fire. This is especially necessary when there is no one attending to the oil control valve, as the sudden increasing of draught usually extinguishes the oil flame, unless proper precautions are taken.

During the run.

(4) *Complete atomization.*

(*a*) The coal fire guarantees the complete atomization of the oil and prevents the formation of carbon deposits on the brickwork and/or in the firepan which may cause explosions in the firebox as proved by experience on U.S.A. railways. On oil-fired steam locomotives without a coalfire, insufficient spray results in the oil not being carried far enough into the firebox and therefore not being properly burnt. In that case oil drops from the burner into the firepan and, if this condition is continued, the oil is liable to run out of the firepan to the ground with consequent danger of a fire starting underneath the engine.

(*b*) It is particularly important to give special attention to this feature when locomotives are being fired up, as the fire is more likely to go out when the brickwork is cold than when the bricks are fully heated.

(*c*) Complete atomization of the oil prevents also the formation of carbon deposits in the tubes. There is thus no necessity for fitting any special sanding device for tube cleaning.

(5) *Improved heat generation.*

Only one oil burner, fitted in the centre of the lower part of the tube plate, is considered as not advantageous by certain railway administrations, as its flame covers the corners of the firebox too little, which may result in temperature losses, and ultimately in bad steaming, while a twin-burner arrangement guarantees an overall heat generation.

(6) *Observation of functioning of burners.*

The arrangement of twin burners spraying towards the tube plate makes it much easier for the fireman to observe the proper functioning of the burners, as he can see the tips of burners when opening the firehole door.

(7) *Re-lighting of burners.*

The re-lighting of burners during the run, should the flame go out through a sudden strong exhaust caused by wheel slipping or the sudden opening of the regulator, is done automatically by the coal fire. There is thus no necessity to re-light the burner either from the red hot firebricks or by placing burning oily waste in front of the burner through the firedoor or through the inspection hole.

According to the current American instructions the practice of re-lighting the burner from the brickwork is considered dangerous and is strictly forbidden, as it frequently causes explosions which damage the brickwork and may result in personal injuries to the crew.

On oil-fired steam locomotives without a coal fire, the possibility exists that when the oil flame has been extinguished the fuel oil may flow through the firepan to the ground with danger of ignition and consequent fire risks to surrounding inflammable objects.

White or milkcoloured smoke at the chimney of an oil-fired locomotive is an indication that the fire has gone out and that the oil is flowing on to the hot brickwork in the firepan. This white coloured smoke is a highly explosive gas and before re-lighting the fire, the oil should be shut off and the firebox cleared of explosive gases.

(8) *Cleaning of burners.*

The twin-burner arrangement makes it possible to clean the burners alternatively while the engine is working. This can be done when standing, coasting or when the output of one burner is sufficient to keep the required steam pressure in the boiler.

(9) *Shutting-off of burners.*

When coasting or standing for comparatively long periods the oil burners can be shut-off completely, as the coal fire retains the heat necessary to keep the steam pressure at the required level, which results in a saving of fuel oil.

(10) *Boiler maintenance and repairs.*

The over-all maintenance and repair costs for boiler and firebox are considerably reduced. The coal fire prevents a too rapid cooling-off of the firebox and thus the frequent and considerable changes in temperature which occur on oil-fired steam locomotives without a coal fire, and which have a damaging effect on tubes, stays, etc., especially in steel fireboxes.

The maintaining of an even temperature in the firebox is extremely important. The respective current American instructions are quoted below :

« Care should be taken to maintain an even temperature in the firebox. It should not be increased too rapidly by forcing the fire or reduced suddenly by permitting cold air to pass through the firebox and tubes. It is of

the utmost importance that this even temperature be maintained to preserve the life of the firebox and tubes and to prevent locomotive failures by leaking of same. »

(B) **Operational disadvantages.**

(1) Coal has to be carried on the tender as well as fuel oil.

(2) Ash and clinker have to be disposed of.

(3) The working of twin burners fitted at the rear of the firebox makes more noise than that of a single burner fitted on the front of the firebox.

(C) **Economic advantages.**

(In coal producing countries without indigenuous resources.)

(1) Less fuel oil is consumed than on oil-fired steam locomotives without a coal fire, while the consumption of low-grade coal is negligible. Moreover, open-cast coal, peat, lignite or the residues from the « washeries » which are now being dumped, can be used to advantage.

(2) When coal-burning locomotives have to be converted to oil-firing the conversion work is less and can be carried out quicker as no alterations have to be made to the grate, such as fitting of fire-pans, etc.

III. State of development of oil-burning steam locomotives in various countries.

Argentina.

(A) *General.*

On the 1st September 1946 there were 3 924 steam locomotives on the Argentine railways, which can be sub-divided, according to the kind of fuel they use, into :

Oil-burners	1 225
Coal-burners	633
Wood-burners	2 066
	3 924

During World War II the Argentine railways were forced to fire home-grown wood, as coal could not be imported and fuel oil was also unobtainable. This led to a serious decrease in the gross tonnage of freight traffic hauled, as the power output of the locomotives was reduced owing to the lower calorific value of the firewood. Thus, as soon as fuel oil became again more easily available the railways increased its use on steam locomotives.

The fuel position on the Argentine railways was reviewed in the 4th April 1947 issue of the *Railway Gazette*, London, from which the following interesting data are quoted below :

« Comprehensive statistics representing all railways in Argentina for the year 1944-45 to hand recently, throw interesting light on the varied character of the fuel supplies on which the companies had to rely to maintain their services at the close of the war. The tonnage of the different types consumed and the average costs per ton were as follows :

	Tonnage.	*Cost per ton.*
Coal	249 404	£4. 4. 0d.
Petroleum	609 446	£6. 0. 0d.
Firewood	4 267 734	19. 2d.
Linseed and other seeds	37 625	£3.13. 0d.

Costs in Argentine pesos have been converted at 16.50 = £1.

In Argentine, the calorific values of the fuels used on locomotives are computed as hereunder :

	Calories per kilogramme.
Coal	7 500
Petroleum	10 500
Firewood	3.500
Linseed and other seeds	4 000

Based on the foregoing calorific values, the relative costs of the different fuels, in terms of coal equivalents, were :

Coal	£4.14.0d.
Petroleum	£4.12.0d.
Firewood	£2. 0.2d.
Linseed and other seeds	£6.17.0d.

Though firewood appears te be the most economical fuel, such is far from being the case. Apart from calorific value, important factors have te be borne in mind, among them

the very long hauls to bring supplies from the forests up country to the running sheds, the heavy cost of which is magnified by the much larger tonnage required. Also, the use of firewood necessitates the employment of a wood-passer on the footplate, and the re-fuelling of locomotives twice as frequently as when coal is burned, adds considerably to costs. Finally, there remains perhaps the most serious disadvantage of all. Coal provides a return load for grain wagons from ports of shipment, which would otherwise return empty to the loading stations in the interior, whereas firewood accentuates the already predominant one-way traffic from the agricultural zones to points of export. »

(B) *Performance of oil-burning steam locomotives.*

It has been found in Argentina that an oil-fired locomotive can average 9 000 kilometres (5 592 miles) a month, as against 6 000 kilometres (3 728 miles) of a coal-fired and 4 000 kilometres (2 485 miles) of a wood-fired locomotive.

The average locomotive run with a freight train is about 600 kilometres (373 miles). Thus the number of freight train trips per month can be calculated for the different kinds of fuel as follows :

Fuel oil : $\frac{9\,000}{600} = 15$ trips.

Coal : $\frac{6\,000}{600} = 10$ trips.

Firewood : $\frac{4\,000}{600} = 6.66$ trips.

As the average freight train weight is about 700 tons the tonnage which may be hauled monthly can be calculated as follows :

With an oil-fired locomotive : $15 \times 700 = 10\,500$ tons.

With a coal-fired locomotive : $10 \times 700 = 7\,000$ tons.

With a wood-fired locomotive : $6.66 \times 700 = 4\,662$ tons.

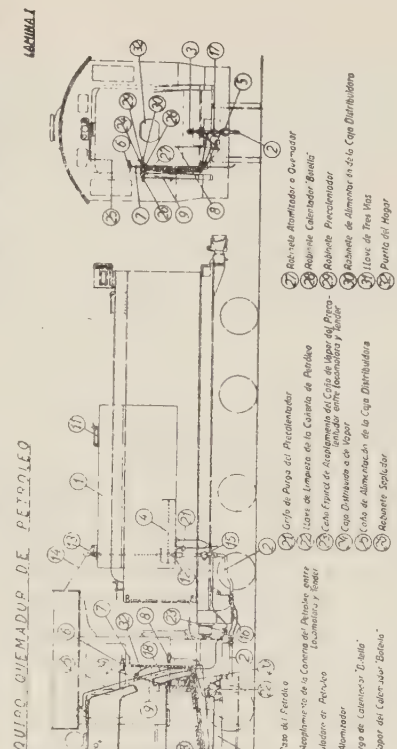


Fig. 3. — General layout of oil-burning equipment in use on the Argentine State Railways.

Explanation of Spanish terms :

1. Oil tank.
2. Oil pipe.
3. Burner slits
4. Oil pre-heater.
5. « Botella » heater.
6. Oil regulating lever.
7. Regulator handle for the air opening of the burner.
8. Regulating lever of the air opening of the ashpan.
9. Blower pipe.
10. Firebox brick arch.
11. Filling orifice of the oil tank.
12. Control valve.
13. Emergency shut off cock.
14. Cable of the emergency off cock.
15. Shut off cock for the oil.
16. Oil hose-pipe between tender and locomotive.
17. Oil valve regulator.
18. Atomiser pipe.
19. Drain valve of the « Botella » heater.
20. Steam pipe of the « Botella » heater
21. Drain valve of the preheater.
22. Valve for the oil-pipe cleaner.
23. Steam-pipe coupling for pre-heater between tender and locomotive.
24. Steam chamber.
25. Supply pipe of the steam chamber.
26. Blower cock.
27. Atomiser or burner cock.
28. « Botella » heater cock.
29. Pre-heater cock.
30. Supply cock of the steam chamber.
31. 3-way cock.
32. Firebox door.

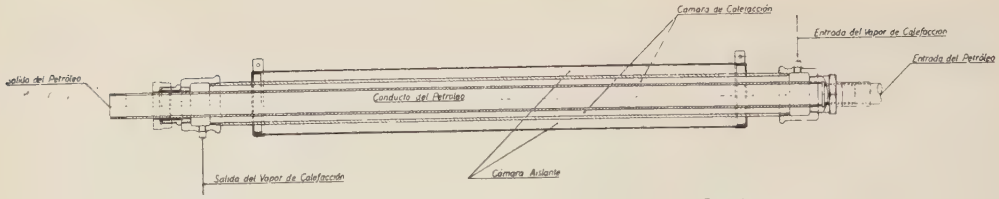


Fig. 4. — Cross section of the « Botella » heater.

Explanation of Spanish terms :

Calentator « Botella » = « Botella » heater. — Camara de calefaccion = heating chamber. — Entrada del vapor de calefaccion = heating steam inlet. — Entrada del petroleo = oil inlet. — Camara aislante = insulating chamber. — Salida del petroleo = oil exit. — Salida del vapor de calefaccion = steam exit. — Conducto del petroleo = oil conduct.

These data show that the same number of locomotives will haul a greater tonnage when fired with oil than when fired with either coal or wood.

In Argentina the following advantages, from an operating point of view, are claimed for oil-fired locomotives :

(*a*) Better utilization of locomotives ;

(*b*) Increased power output per locomotive;

(*c*) Greater regularity of service, which means, in turn;

(*d*) Fuller utilization of locomotive staff since the number of ton kilometres per man-day is greater.

(C) *Oil-burning equipment used.*

The oil-burning equipment in use on the Argentine State Railways is of the American type and consists of a single burner mounted at the lower part of the tube plate (*Fig. 3* gives the general lay-out of this equipment, while *Fig. 4* gives a cross section of the *Botella* heater). The oil-fired locomotives are fitted with a burner control device — the invention of an Argentine railway engineer — which provides for the automatic control of the oil and steam supply to the burner *(see Fig. 5)*. Thus the fireman operates only one handle instead of the two (oil control and steam control valve) on the two systems described in Section II of this article.

(D) *Effects on health of locomotive staff.*

As to the effects on the health and comfort of locomotive staff the experience gained in Argentina can be summarized as follows :

The petroleum derivative which is used on oil-fired steam locomotives is known as « fuel oil ». It is not harmful to the health of the staff as the gases given off are not dangerous like those of « gas oil » which, according to Dr. Roffe, an Argentine scientific authority, is a cause of pulmonary cancer.

This is confirmed by the lengthy experience the locomotive men have had. They have never felt any symptons which have later been shown as having been caused by the exhaust gases of the « fuel oil ». Only if the burner is not working properly the gases reaching the locomotive crew cause some discomfort to the respiratory organs, but they have no after-effects and the discomfort ceases as soon as fresh air is breathed again.

Oil-firing means greater comfort to the footplate staff at their work. This is particularly true of the fireman who has none of the heavy work to do which the shovelling of coal or of any other solid fuel calls for. The way in which the oil is carried and handled in use leaves more free space in the cab. It also makes it possible to keep the cab cleaner which

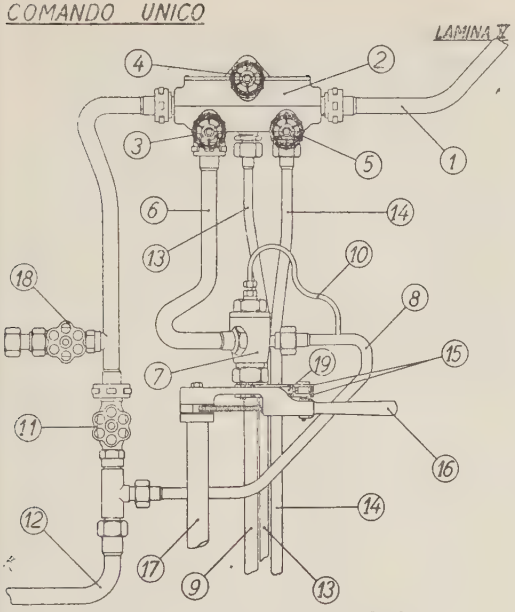


Fig. 5. — Burner control device.

1. Steam pipe from boiler (small dome).
2. Steam supply chamber.
3. Steam valve to burner.
4. Steam valve to « Botella » heater.
5. Steam valve to pre-heater.
6. Pipe leading to the control valve of the burner
7. Control valve of the burner.
8. Pipe to the automatic blower (single control).
9. Atomiser pipe.
10. Drain to the burner control valve.
11. Independent blower cock.
12. Blower pipe.
13. Steam pipe to the « Botella » heater.
14. Steam pipe to the pre-heater.
15. Connection between the single controller and the burner regulator valve.
16. Single control handle.
17. Single control lever shaft for oil regulator and air admission.
18. Steam admission valve for ignition.
19. Lower cone.

obviously means more comfort for both driver and fireman.

Austria.

(A) *Development prior to 1945.*

Oil-fired steam locomotives were in operation prior to and during World War I on the heavily graded Tauern and Wocheiner lines. The reason was the availability of crude oil from Galicia — then part of Austria — which had to be used. Moreover, the long steep gradients of those two Alpine railways made such heavy demands on the strength and endurance of the firemen of coal-fired locomotives that only the strongest men could stand it. On these two lines oil-firing was economically justified, as with coal-fired locomotives two firemen — each firing for short periods — would have been necessary.

After World War I the Wocheiner line was ceded to Jugoslavia, while the Tauern line was electrified.

The experience gained with oil-fired steam locomotives on these two Alpine lines can be summarized as follows :

(1) The disadvantage of the bad smell and the increased dirt were accepted by the locomotive staff.

(2) The noise of the burners was found to be very irritating and made communication between driver and fireman difficult; when the locomotive was working hard they could only make themselves understood by signs; acoustic signals were difficult to understand.

(3) Cases occurred where locomotive and train staff were asphyxiated by fumes when passing through long tunnels.

(4) The coaching stock circulating on the lines operated by oil-fired steam locomotives required more intensive cleaning than stock used on other lines, as the interior of the coaches became impregnated with the residue of the greasy exhaust; the upholstery was always dirty.

With the electrification of most of the mountainous main lines in the years following World War I, and with regular coal imports from neighbouring countries assured, the necessity for oil-fired locomotives ceased to exist.

(B) *Development since 1945.*

At the end of 1945 and the beginning of 1946 the serious coal shortage, as well as the development of indigenuous oil resources in Lower Austria made a reintroduction of oil-fired steam locomotives necessary. About 200 locomotives of different classes were fitted with Hardy or Swoboda oil-burning equipment. This equipment provides for twin-burners fitted at each side of the firehole door. The grate remained unaltered, so that, according to the fuel position, either straight oil-firing (in which case the grate was covered up with firebricks or slack after due allowance had been made for a sufficient air admission) or mixed coal-oil firing (in which case the oil flames pass closely above the layer of coal) or, if need be, straight coal-firing could be used.

In the beginning of 1947 a locomotive of the 52 class was fitted with the American-type oil-burning equipment, i.e., a single burner fitted at the front of the firebox and spraying towards the cab. This locomotive is at present in service on the Vienna-Attang Puchheim section. The operating results are considered satisfactory.

As regards boiler maintenance and repair of straight oil-fired locomotives it can be said that copper fireboxes stood up well. On the other hand, steel fireboxes have shown damages (broken stays, cracks in the tube- and side plates, etc.) very frequently.

(C) *Economic aspects.*

As to the economic aspects of oil-firing the Austrian State Railways have so far, no reliable data available. Dynamometer car tests carried out with a small locomotive (D.T.1.02) in February 1937 which had been fitted with two Hardy burners (of small capacity) gave the following fuel savings when comparing straight oil-firing with coal-firing :

For a boiler performance of 40 kg./sq. metre per hour, a saving of 5.1 per cent;

For a boiler performance of 57 kg./sq. metre per hour, a saving of 7.8 per cent.

This saving rapidly increased up to 18 per cent in cases of maximum boiler performances of 100 kg./sq. metre per hour, which, however, only occur for short periods in locomotive operation.

Due to lack of suitable measuring instruments it is not possible to provide reliable fuel consumption figures for oil-burning locomotives. Although a fuel saving of about 6 to 8 per cent may be achieved when comparing straight oil-burning locomotives with coal burners under present conditions it must be born in mind that nowadays coal of very inferior quality has to be fired.

The Austrian State Railways are very doubtful if oil-firing of steam locomotives will ever be an economical proposition. In view of the fact that the Austrian Government has decided on electrification of all Austrian main lines, the use of oil-fired steam locomotives is considered as only a temporary emergency measure.

(D) *Effects on health of staff.*

As stated under item (A) — see page 849 — cases occurred where locomotive and train staff were asphyxiated by fumes when passing through long tunnels. Moreover, a number of cases are known where crews, after having worked oil-fired steam locomotives for a short time, complained of ear trouble and showed various nervous diseases. Finally, employees who are sensitive to oil get dermatitis which is rather difficult to cure.

Belgium.

The Belgian National Railways have so far converted five coal-burning locomotives, which were originally built in Great Britain, to oil-firing for experimental purposes. The oil-burning equipment fitted is similar to that described in detail on pages 838-840.

Brazil.

Brazil has plenty of coal of very poor quality (2 000-4 000 kgr./cal.). The firing of this coal in locomotives is very uneconomical. Certain Brazilian railways decided, therefore, to fire their locomotives with a mixture of oil and coal; they stipulated that the maximum amount of coal should be fired with the minimum amount of oil.

Tests were made with such locomotives during World War II, but had to be abandoned owing to the difficulty of oil. No information is available to indicate whether these tests were resumed in 1945 and whether such locomotives are now in regular service.

Denmark.

The coal shortage induced the Danish State Railways to experiment with oil-burning steam locomotives in 1946. Two test locomotives were converted from coal to oil-firing but no details as to the equipment used and the results obtained are as yet available.

Egypt.

In 1936 the Egyptian State Railways introduced oil-burning on their 4-4-0 (2-B-0) steam locomotives, which were built by the North British Locomotive Company (*).

The burner is located at the front end of the firepan, with a small primary air door beneath it *(see Fig. 6)*. An extension, or air chamber, is welded to the bottom plate of the firepan, with a damper door at the front end, operated from the footplate. The main air inlet, from the air chamber to the firepan, is arranged at a suitable distance in advance of the burner, and forms also a manhole through which access to the firebox is obtained. An access door is fixed by studs to the bottom plate of the air chamber. The burner is of gunmetal with a lip piece fixed over the steam outlet which is 2 in. wide by about 0.018 in. deep.

The other parts of the oil-burning equipment are similar to that described in detail on pages 838-840.

Until now over 500 steam locomotives of the Egyptian State Railways have been converted to oil-firing with great success. The conversion work has been carried out in the railway workshops.

No ill-effects on the health of the staff have been reported.

France.

(A) *Development prior to 1944.*

In France, oil-firing of steam locomotives has been used repeatedly. It had its biggest test in the period following World War I when, due to the coal shortage, the majority of the French railways showed a keen interest in it. As soon as the cost of oil increased and coal became again available, the locomotives were re-converted from oil to coal-firing.

Certain railways, however, continued their tests; for example the P.O. Railway fitted in 1934 locomotive 141.854 with Pillard burners and also equipped in 1939 Pacific engine 231.528 for oil burning. Moreover, the Etat Railway fitted

(*) See *The Railway Gazette*, 10th December 1937.

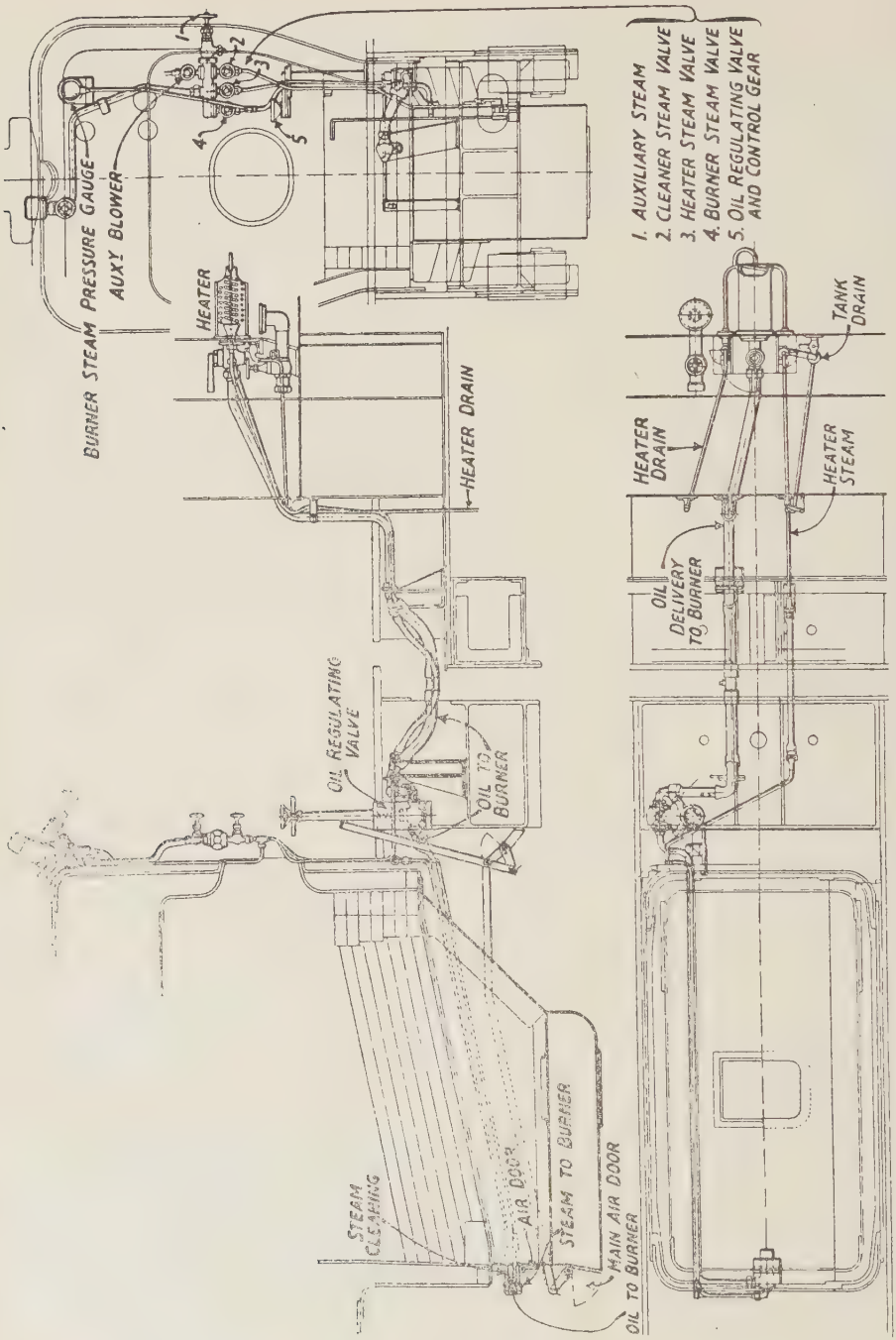


Fig. 6. — Oil firing arrangements on locomotives of the Egyptian State Railways. *(The Railway Gazette.)*

Pillard burners to engine No. 140.1387 and to engines of the 131 class.

The Pillard burners fitted on locomotive 231.528 of the P.O. Railway works with oil under pressure and uses two steam circuits with different pressures (*).

(B) *Development since 1944.*

(1) *Utilization of oil-fired locomotives in the South-Eastern Area of the French National Railways* (**).

The locomotives of class 140 which the Americans began to use in France in the autumn of 1944 were built partly for coal and partly for oil-firing.

The average number of oil-fired steam locomotives in service in the South-Eastern region during the period November 1944-May 1945 was about 65.

The allocation of these engines during the period January-May 1945 was as follows :

Name of motive power depot.	*Average number.*
Marseilles-Blancarde	16
Lyons-Mouche	16
Dijon-Perrigny	32

The 32 locomotives of the Lyons-Mouche and Marseilles-Blancarde motive power depots were exclusively used for the through haulage of military freight trains from Marseilles to Lyons (352 kilometres = 221 miles) and vice versa.

The oil tanks on the tender of these locomotives had a capacity varying from 6 to 7 cubic metres (211.88 to 247.2 cubic feet). The calculated oil consumption was about 20 litres per kilometre (7 gallons per mile) which was often very considerably exceeded especially under adverse weather conditions.

During the period January-May 1945 the number of military freight trains run daily between Marseilles and Lyons varied between 15 and 20. The average weight of such train was 1 000 tonnes and the average booked speed 45 kilometers per hour (28.1 miles p.h.). In case of late running it was possible to make up about 3 hours on a through run without any difficulties, which shows that the engines were not scheduled to work continuously at maximum capacity.

In March 1945 the average monthly performance of a serviceable locomotive was 8 900 kilometres (5 530 miles) or 287 kilometres (178 miles) per engine per day and 340 kilometres (193 miles) per day per engine in use. The average duration of a single run from Marseilles to Lyons during March 1945 took about 18 hours.

These monthly performance figures were said to be due to two facts, namely :

(*a*) The very high availability due to extensive maintenance work carried out by specialized staff; and

(*b*) The oil-firing which requires only 90 minutes for lighting-up, which does not need any time for preparing and cleaning of the fire and which has not the drawbacks inherent in the firing of coal of inferior quality.

(2) *Details of current conversion programme.*

Owing to the present need of coal for industrial production the French National Railways, on order from the French Government, prepared a large-scale programme for converting coal-fired steam locomotives to oil-firing.

The first step in this programme is

(*) See *Revue Générale des Chemins de Fer*, February 1947.

(**) See *Revue Générale des Chemins de Fer*, May-June 1946.

the fitting of 620 locomotives. All these engines are of the 141-R class, i.e. chosen from the 1 340 locomotives which were ordered in 1945 from the U.S.A. and Canada. One of the reasons for choosing this class of engine was the fact that the necessary equipment could be obtained fairly quickly; 300 locomotives are being fitted for oil-firing by the American builders before being shipped, while another 320 sets of oil-burning equipment will be delivered during 1947. The first engines were put into service in 1946.

Another reason was that the 141-R locomotives are among those with the largest fireboxes which is one of the essentials for firing of oil under good conditions.

When the whole conversion programme has been completed the fuel oil consumption of the oil-burning steam locomotives is estimated to amount to about 1 000 000 tons which corresponds to 11 per cent. of the total coal consumption of the French National Railways, which latter is approximately 9 000 000 tons.

(3) *Oil-burning equipment in use.*

The equipment used on the oil-burning locomotives is of the American type and, in principle, similar to that described on pages 838-840 (*Figs. 7, 8, 9* illustrate the arrangement of this equipment on the 141-R locomotives).

Fig. 7 shows three air admission points; one around the burner, the second in the firepan and the third around

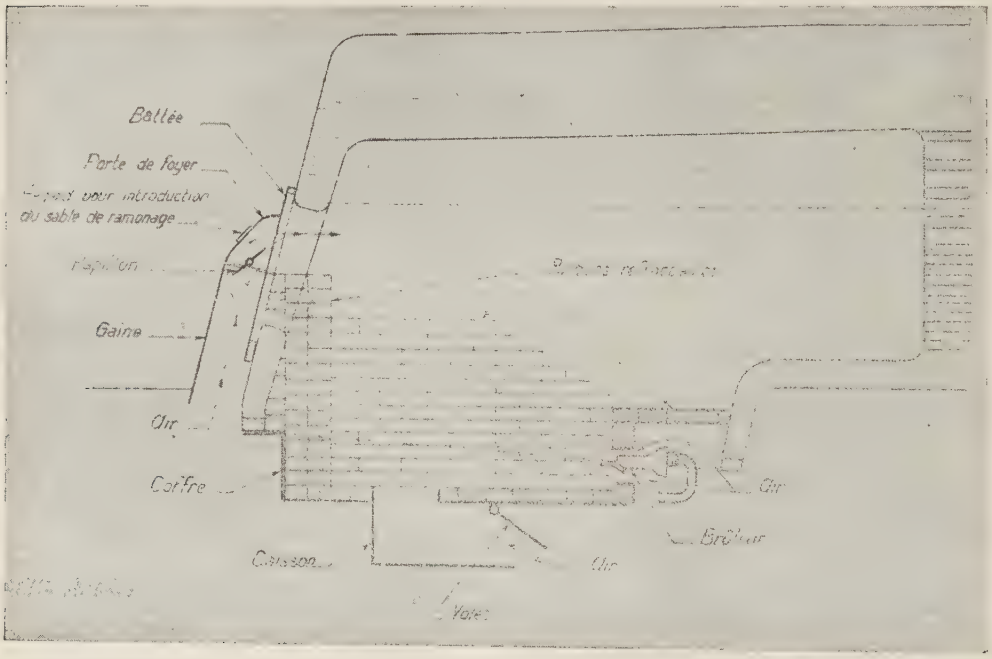


Fig. 7. — 141-R locomotive. Fire-box layout.

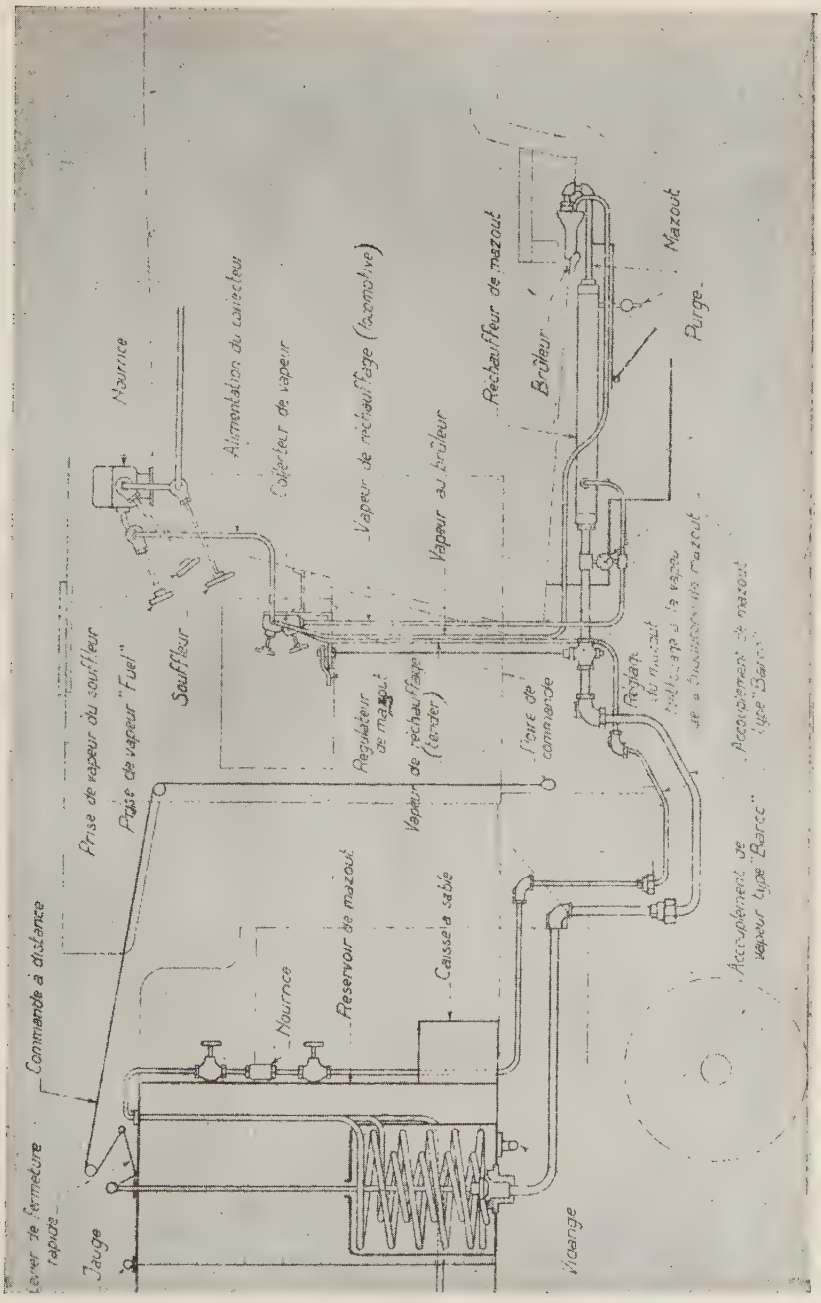


Fig. 8. — 141-R locomotive. — Locomotive and tender equipment.

141-R LOCOMOTIVE.

Arrangement of the controls

Back end arrangement of locomotive.

Front end arrangement of tender.

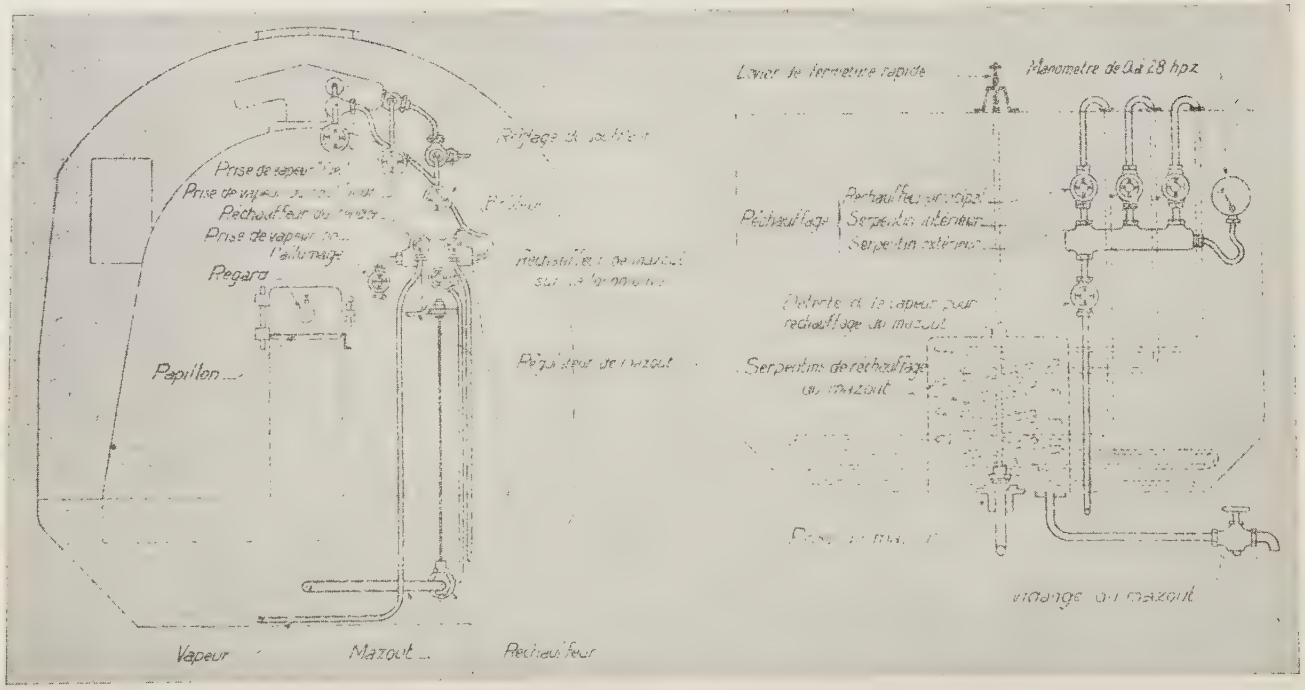


Fig. 9.

the firedoor. The main admission point is in the firepan; it is estimated that about 70 per cent. of the air is admitted through this opening, 20 per cent. through the opening around the burner and only 10 per cent. through the opening around the firedoor. The latter opening is only of secondary importance as far as the admission of air is concerned; its main object is to permit of the introduction of sand for tube cleaning purposes. The tubes should be cleaned every 30 minutes when the engine is working.

The bricking-up of parts of the firebox is important with this type of oil-burning equipment. The engine will not steam as well without the brickwork as the sheets, being in contact with water, are too cool to flash the oil readily and hence the use of a refractory lining and of a « flash wall » heated to a high temperature aids combustion very materially.

The spaces between bricks are filled with a mixture of fire clay and water thoroughly mixed to a consistency of a thin paste, in order to keep cold air from being drawn in.

The temperature of the oil flames is very high and superior to that of coal, i.e. 1 700 degrees Centigrade (3 092 degrees Fahr.) instead of 1 350 degrees Centigrade (2 462 degrees Fahr.).

(4) *Economic aspect.*

Certain economic results achieved with oil-fired locomotives were published in the February 1947 issue of the *Revue Générale des Chemins de Fer* and the following data are quoted therefrom :

« For the American locomotive of the 140-class which operated in France in 1945-46 the consumption measured at the Vitry testing station at a speed of 40 kilometres per hour (24.84 m.p.h.) and at an output of 800 CV (788 H.P.) was 1.02 kgr. (2.25 lb.) of coal for a coal-fired locomotive and 0.86 kgr. (1.89 lb.) of fuel oil for an oil-fired locomotive, giving a ratio of about 1.2 which corresponds to the calorific values of the two fuels — 7 700 kgr./cal. for coal and 9 900 kgr/cal. for oil. In actual operation however the ratio was more in the region of 1 and thus lower than that quoted above. Steam consumption for the pre-heating and atomization of the oil is approximately 1-3 per cent. of the total consumption. »

(5) *Cost of conversion programme.*

The total cost of the conversion programme is estimated at more than 500 000 000 francs, which includes the cost of the equipment, its installation on the locomotive and the erection of storage tanks at refuelling stations. The cost will be equally shared by the French National Railways and the French Government.

(6) *Advantages claimed for oil-fired steam locomotives.*

Although it is realised that oil-fired steam locomotives cannot compete with Diesel locomotives, they are said to have a number of advantages over coal-fired locomotives, apart from the saving of coal. These advantages are :

(*a*) the trains are cleaner;

(*b*) the locomotive fuel is carried more easily;

(*c*) the controls are simplified; and

(*d*) the time required for steam raising is halved.

Great Britain.

(A) *General.*

In Great Britain, oil-burning has not been regarded as an economic proposition during the present century. During

the prolonged coal strikes of 1912, 1921 and 1926 however, various railways introduced oil-burning locomotives, principally working on the Holden and Scarab systems. In 1921 for example, some 116 locomotives were equipped to burn fuel oil, while in 1926 considerable numbers of 4-6-0 and 4-4-0 passenger locomotives were adapted to burn fuel oil on the London Midland & Scottish Railway. The oil-burning equipment fitted to these engines only required the addition of a firebrick lining beneath the brick arch in the firebox to protect the lower part of the tube plate, and a layer of broken firebricks on the firebars. The burner was inserted through the firedoor, and supplied with dry steam from a fitting on the back of the boiler. The initial pressure of about 35 lb./sq. in. required to work the burner was raised by means of a wood fire.

As soon as the coal strikes were over and coal was again available for traction purposes the oil-fired steam locomotives were re-converted into coal burners.

(B) *The Great Western Railway's experiments.*

After World War II the Great Western Railway began to make large-scale experiments with oil-fired locomotives. The reason for these was the very high price of locomotive coal, which, it was stated, may make oil-firing of steam locomotives an economical proposition. The results achieved were not discouraging. The average fuel oil consumption of a heavy freight locomotive hauling a 700-ton train was 6 gallons per mile compared with 75 lb. of coal which gives a ratio of

$$\frac{75 \text{ lb.}}{6 \text{ gallons}} = 1.25.$$

(C) *The 1946 conversion scheme.*

In this scheme, authorized by the Minister of Transport at the end of August 1946, the four main lines are to convert 1 217 coal-burning locomotives to oil-firing as quickly as possible, in order to secure a saving of coal estimated at 20 000 tons per week or approximately 1 000 000 tons per year. The Minister of Supply undertook to furnish all the equipment necessary for the conversion, and the North British Locomotive Company was appointed chief contractor The oil-burning equipment to be provided is similar to that described in detail on pages 838-840.

The three main features of this big conversion scheme are :

(*a*) the alterations on the locomotives;

(*b*) the erection of oil storage installations in some 58 locomotive depots; and

(*c*) the construction of some hundreds of rail tank wagons for transporting the oil from the storage depots. These wagons are being fitted with steam heating coils to keep the oil fluid.

The number of locomotives to be converted by the individual railways are :

Railway.	*Number.*
London, Midland & Scottish .	485
London & North Eastern . .	450
Great Western	172
Southern	110
	1 217

Only heavy-duty locomotives which consume a large amount of fuel will be converted, as can be seen from the following table :

Railway.	*Class of engine.*	*Number.*
London Midland & Scottish	Garratt	33
	0-8-0 Class 7	175
	2-8-0 Class 8	266
	2-8-0 S. & D.	11
		485
London & North Eastern	04	112
	01	39
	W.D. Austerity	111
	2-6-0 K3	91
	2-8-0 Q6	46
	0-6-0 J39	35
	02	16
		450
Great Western	28xx	63
	49xx	84
	Castle	25
		172
Southern	West Country	20
	N15 and H15	16
	N. & U.	34
	D15	10
	L11.T9	30
		110

Considering the variety of types concerned, complete standardization of some of the parts of the oil-burning equipment is impossible.

At the end of August 1947, 49 oil-fired steam locomotives were operating (37 on the Great Western Railway, 5 on the Southern Railway, 6 on the London Midland & Scottish Railway, and 1 on the London & North Eastern Railway). Shortage of material required for the oil storage tanks, etc., is the main reason why this conversion programme, which was to be completed by April 1947, had not even been started in earnest by the end of August 1947, although it was given « top priority ».

Italy.

(A) *General.*

Since 1944 the Italian State Railways have 260 American oil-fired steam locomotives in servive. The oil-burning equipment in use is similar to that fitted on the 141-R locomotives of the French National Railways (see pages 854-857).

(B) *Accidents.*

A number of explosions occurred on

these oil-fired locomotives which may have been caused by the lack of experience of the Italian staff operating them. However, it is worth while to mention here that the Italian State Railways consider it of great importance to keep the boilers of oil-fired locomotives free of scale, in order to prevent damage to tubes, stays, etc. by the rapid expansion caused by the steep rise in temperature in the firebox when the burner is working. Scale which has formed at certain places impedes the even transmission of heat and results in undue stresses which may cause cracks and other major damage.

(C) *Effects on staff.*

Italian experience with oil-fired steam locomotives shows that the manual work of the fireman is greatly reduced. On the other hand, his work is far more skillful than on coal-burning locomotives. For this reason the Italian State Railways consider it absolutely essential to give the crews of oil-fired steam locomotives a very thorough training.

(D) *Latest conversion programme.*

The serious coal position forces the Italian State Railways to convert some of their small coal-burning shunting locomotives as well as a number of their own freight locomotives to oil-firing.

Middle Eastern Countries (Excluding Egypt).

During World War II most of the railways in the Middle East converted a considerable number of their coal-burning locomotives to oil-firing.

All British War Department (W.D.) locomotives used on the railways of Middle Eastern countries were designed in such a way as to allow conversions from coal to oil-firing without lifting the boilers from the frames. Normally this is necessary to permit of the removal of the ashpans and the application of special firepans. Therefore a simple form of false bottom was introduced, constructed of narrow sections which could be inserted through the fireholes or ashpan doors. These bottom plates, secured within the coal-burning ashpan, were provided with apertures or air inlets and bricked up to form a firepan for oil-burning. The existing ashpan doors were used to regulate the air admission to the firepan.

New Zealand.

The acute coal shortage induced the New Zealand Government Railways to convert two coal-burning locomotives to oil-firing for experimental purposes. As the tests were satisfactory, the administration decided in January 1947 to convert about 25 coal-burning locomotives to oil-firing. The oil-burning equipment in use is similar to that described in detail on pages 838-840.

Rumania.

Political and economic considerations were the main reasons for the introduction of oil-firing on the Rumanian State Railways prior to World War II. A further consideration was the fact that Rumania has an abundance of indigenous crude oil *(mazut)*.

The oil-burning equipment in use is similar to that described on pages 842-844.

As far as fuel oil consumption and locomotive performance are concerned, the following information given by Professor A. Zanesco in an article on the 2-8-4

(1-D-2) heavy passenger train locomotive of the Rumanian State Railways is interesting (*) :

« The firebox is built for firing a mixture of *mazut* and low-grade coal. Two oil burners are fitted, one on each side of the firedoor. The fuel oil *(mazut)* consumption per hour varies from 1 400 kilogrammes at 75 kilometres per hour and 25 % cut-off, to 2 200 kilogrammes at 58 kilometres per hour and 40 % cut-off, or 92 kilometres per hour and 30 % cut-off; it exceeds 2 500 kilogrammes at a speed of 110 kilmetres per hour and 30 % cut-off. »

« When comparing the performance of this class of locomotive with that of the coal-fired class 214 of the Austrian State Railways, it can be stated that the Rumanian locomotives give better performances due to the firing of a mixture of fuel oil and low-grade coal. This results in a better combustion process in the firebox and so in a better steam generator in the boiler. »

United States of America.

(A) *General.*

As stated in Section I, in 1943 there were 6 700 oil-burning steam locomotives in operation on Class I railways of the United States. During the period 1912-1943 their number increased steadily. The purchases of fuel oil for these locomotives rose continuously during the same period; they increased from 1 942 797 000 gallons in 1933 to 4 802 297 000 gallons in 1943 and amounted to 4 702 562 000 gallons in 1945. The prices of fuel oil increased steadily from 1.369 cents per gallon in 1933 to 2.635 cents in 1943, but decreased slightly during 1944 and 1945.

The following table shows the percentage increase in volume and price of the three kinds of fuel used on United States railways in 1946 as compared with 1933 :

Kind of fuel.	*Increase in volume in per cent.*	*Increase in price in per cent.*
Coal	48.4	63.0
Fuel oil	112.2	111.0
Diesel oil	8 362.0	68.0

(*) See *Bulletin de l'Association Internationale du Congrès des Chemins de fer*, December 1946, p. 465. (French edition.)

(B) *Oil-burning equipment in use.*

(1) *Types of burners.*

The principal parts of the « American type » oil burning equipment are described on pages 838-840. The oil burner which is generally used, is a brass casting containing two parts, the atomizer, or lower opening in flat burners or outer annular openings on round burners, and the oil port which is the upper opening in flat burners and the centre opening in round burners. Some flat burners are provided with an extension lip below the atomizer port to aid the steam in atomizing the oil and to prevent the oil from dripping down. The burner is usually located in the forward end of the firepan lined to strike the opposite flash wall at a proper distance above the bottom of the firepan.

Burners of different sizes (3.5, 2.5, 2.0 and 1.5 in. wide) are in use according to the types of locomotives.

(2) *Tube cleaning device.*

For tube cleaning purposes every oil-fired locomotive is equipped with an elbow-shaped scoop or funnel. The tube cleaning is done by placing a small quantity of thoroughly cleaned and dried sand in the funnel and by inserting it into the firedoor hole while the engine is working hard, thus allowing the exhaust to draw the sand through the tubes,

cutting the soot from them in its passage and then discharging it from the chimney. It is better to use sand frequently, and a small quantity at a time, about every 10 miles or every 30 minutes, than to use large amounts only a few times during a run.

It is necessary that the tubes are cleaned of carbon deposits on leaving the shed or a siding where the engine has been at rest for any length of time and also as often as found necessary to aid the engine in steaming. Attention must be given to the tubes just prior to the engine being stabled at a shed in order to leave them clean. This facilitates the lighting-up in cases where the blower alone has to be relied upon for draught.

(3) *Safety oil valve on tender tank.*

This safety oil valve controls the flow of oil from the fuel oil tank through an opening in the bottom sheet of the tank to the pipes leading to the burner. This oil valve is forced to its seat by a heavy spring and is held off its seat by a key in an upright rod extending above the top of the tank. To this key a chain or wire cable is attached which is also attached to the cab to cause the pin in the rod to be pulled in case of a separation between engine and tender and allows the valve to be seated by its spring.

In case of fire in the cab or accident of any description, the crew has to pull the oil valve cable immediately in order to close this valve. Thereafter the shut-off valve under the tender deck has to be closed by pulling out the handle of the shut-off valve, which prevents oil from running out and thus lessens the danger of fire.

(4) *Heating of fuel oil in tender.*

A number of American oil-burning steam locomotives are fitted with :

(*a*) A thermostat for controlling the temperature in the tender heating coil.

(*b*) A dome fitted to the fuel oil tank on the tender to allow for the expansion of the heated oil. The design generally used is of rectangular shape, 6 ft. long, 37 in. wide and about 10 to 11 in. high.

On engines which have fuel oil tanks without a dome, it is the practice not to fill the fuel oil tanks quite full, in order to allow for the expansion of the heated oil; for example, a 4 500 gall. tank will be filled with 4 100 gall. only. On the other hand, on fuel oil tanks fitted with domes, the tanks can be filled to capacity.

(*c*) Moreover, oil-burning steam locomotives equipped with a thermostat and expansion dome have the heating coils in the tender in a compartment within the oil space; in other words, the heating coils form part of the space at the bottom of the oil tank. This allows for oil in the compartment to be heated first; the compartment holds about 500 gallons. It is, therefore, not necessary to heat the entire tank to get oil of a temperature ready to be fired after taking oil from an unheated wayside tank or at the commencement of the journey.

(C) *Safety regulations.*

It is also interesting to quote certain safety regulations for oil-burning steam locomotives in force on U.S. railways :

(1) Oil lamps or oil torches must not be carried within ten feet of the tank opening. Only incandescent lamps or pocket flashlights should be used around the oil tank manhole when taking oil.

The switching on or off of electric lights near the open man-hole should be avoided, as it may produce a spark which may ignite the oil vapour.

(2) When taking oil and after the valves of the spout have been closed, time must be allowed for the spout to drain before it is removed from the man-hole. Spouts provided with drip pans or receptacles to prevent loss of oil must have same properly applied before the spout is moved away from the man-hole. Careful attention to these matters is necessary in order to prevent waste of oil and to prevent oil being spilled on the top of tanks where motive power staff and others may slip and fall while walking over the top of the tank.

(3) Hot carbon bars must not be placed on top of a tender oil tank as it may result in a serious fire or explosion by igniting oil vapours escaping from the oil tank vent pipe.

(4) When measuring the amount of oil in a fuel oil tank by means of a measuring rod, during the hours of darkness, the rod has to be taken to the light to examine it and not the light to the tank. Before taking measurements one has to be sure that the oil has stopped splashing around in the tank, as a correct measurement cannot be taken until the oil has reached a constant level. Accurate measurements of oil cannot be obtained when the locomotive is in motion, or when the heaters in the tender are on.

When wiping the measuring rod care must be taken that threads of waste do not adhere to it, as they will finally reach the valves and oil pipes and might possibly clog them. Waste should not be dropped on top of the tank or allowed to collect on the tank.

(5) Oil tanks, before being entered by workmen, should be thoroughly steamed out from 6 to 8 hours and then washed out with cold water to ensure the removal from tanks of any gas that may have accumulated. When necessary to have artificial light in an oil tank, only electric flash or incandescent lights should be used.

(6) All engine sheds dealing with oil-burning steam locomotives must be provided with strong barrels of about 50 gall. capacity for storing sand to be used in extinguishing fires. One barrel is to be located between every alternating pair of inspection pits. These barrels must be kept filled with sand and must be inspected periodically to see that they are full of sand and that the sand is dry. The sand must not be used for any other purpose than extinguishing oil fires. An old or scrap scoop must be kept on top of each barrel. Similar fire extinguishing equipment must be kept at oil supply stand pipes.

(D) *Accidents.*

The Interstate Commerce Commission publishes every year a report of its Bureau of Locomotive Inspection on accidents and casualties caused by steam locomotive operation. The most frequent causes of accidents which occur with oil-fired steam locomotives given in these reports are :

(1) Waste fuel oil left on top of fuel oil tank.

(2) Waste fuel oil on engine steps and in cab.

(3) Explosion of pools of oil in the firebox.

(4) Explosion of gas in the firebox.

(5) Back flashes through open fire-doors.

(6) Fire in the cab due to overheated oil, overflowing from the fuel oil tank, being carried forward by strong winds to the cab, where it becomes ignited.

(E) *Wages of firemen.*

(*a*) *Passenger service.*

The present standard basic daily wage rate of firemen of oil-fired passenger steam locomotives is 8 cents (about 1 per cent) lower than that of firemen of coal-burning passenger locomotives for locomotives with a weight on driving wheels of :

80 000 and less than 100 000 lbs.

as well as for all locomotives with an adhesive weight higher than 140 000 lbs.

For passenger steam locomotives with a weight of less than 80 000 lbs, as well as with a weight of 100 000 lbs. and less than 140 000 lbs. on driving wheels the rates for firemen on oil-fired locomotives are the same as those on coal-burners.

(*b*) *Freight service.*

The present standard basic daily wage rate of firemen of oil-fired freight steam locomotives of certain classes is lower than that of firemen of coal-burning freight locomotives, as set out below :

Classification of locomotives. (Weight on driving wheels in lbs.)	*Daily wage rate of firemen on coal-burning locomotives in Dollars.*	*oil-burning locomotives in Dollars.*	*Difference in cents*
less than 80 000	8.78	8.78	—
80 000 and less than 100 000	8.86	8.78	— 8
100 000 and less than 140 000	9.03	8.92	— 11
140 000 and less than 170 000	9.21	9.10	— 11
170 000 and less than 200 000	9.38	9.27	— 11
200 000 and less than 250 000	9.55	9.43	— 12
250 000 and less than 300 000	9.72	9.72	—

For coal-burning and oil-burning freight steam locomotives with an adhesive weight of more than 300 000 lbs. the rates paid to the firemen are the same.

On oil-burning Mallet locomotives in passenger service the rates of firemen are 10 cents lower per day than those for firemen of coal-burning Mallets of the same adhesive weight. On the other hand, the rates of firemen on coal- or oil-burning Mallet locomotives used in freight service are the same.

Uruguay.

The oil-burning equipment in use consists of a burner fitted at the bottom of the tube plate and spraying towards the cab. The burner is of the external mixing type, where the oil and the atomizing agent — steam — meet at the top of the nozzle. It has a corrugated lip projection to prevent oil falling past the sheet of steam, the corrugations being intended to promote atomization. The other parts of the oil-burning equipment are similar to those described on pages 838-840.

Experience in Uruguay seems to indicate that fuel oil tanks with rounded corners are to be preferred to the square-corner type, as the latter are more susceptible to leakages.

It has also been found that the provi-

sion of an electrical pyrometer fitted in the smokebox, with a large-size dial in the cab, has resulted in interest being shown by locomotive crews in their attempts to keep down smokebox temperatures and to burn the fuel oil to the best advantage (*).

IV. Conclusions.

Oil-burning steam locomotives have been in use for a long time in countries with indigenous oil resources. The shortage of coal in the after-war years forced a considerable number of European and overseas railways to introduce this type of firing on some of their locomotives. Although experience in France and Great Britain shows that oil-burning in steam locomotives never lasted long when circumstances permitted a reversion to coal-firing, the present world coal crisis may force the railways of certain countries to use oil-burning steam locomotives for a considerable time.

It is too early to give a reliable verdict on the economic side of oil-burning which, obviously, depends on the relative cost of coal and oil and on the availability of the locomotives. Oil-firing may, however, permit of a higher locomotive mileage for the same weight of fuel. Moreover it does away with clinker, ashes and all the problems caused by poor-quality coal; it may also reduce the smoke nuisance. It certainly reduces the manual work of the firemen.

In order to make oil-firing as economical as possible, it is very important that the staff who work oil-burning locomotives be thoroughly trained. The firing of an oil-burning locomotive differs very materially from the firing of a coal burner. More careful attention is necessary with oil-firing than with coal-firing to render combustion economical.

Firing of an oil-burning locomotive demands that close attention be given at all times in order to produce satisfactory results. To this end the driver and fireman must work in harmony with each other. The driver must advise the fireman of every intended change of position of the regulator or reverse levers so that he can change the fire accordingly. The fireman must be watchful and diligent, for he can save or waste more fuel on an oil-burning locomotive than on a coal burner.

(*) See *The Railway Gazette*, 15th November, 1946.

[656 .226 (.42)]

Expediting miscellaneous traffic on the L.M.S.R.

(The Railway Gazette, January 24, 1947.)

In normal times, the London Midland & Scottish Railway delivers, or advises to consignees for collection, over 110 000 consignments of merchandise traffic daily, and it is reasonable to estimate that a somewhat similar number is collected for despatch on any one day Some of this traffic is conveyed in full wagon loads from one sender to one consignee, but a substantial proportion consists of miscellaneous traffic.

L.M.S.R. delivery vehicle in Chester.

Tests conducted by the L.M.S.R. before the recent war showed that, on an average, such traffic amounted to about three packages per consignment, and approximately 78 lb. per package, while there is, of course, an immense variety in the shape, size and weight of individual consignments. These small consignments may consist of large numbers of packages of standard products from one firm for consignees in towns and villages all over the country, or they may consist of an odd package from a private householder in any town or village destined for a consignee in any other town or village throughout the line.

The throughout transit of these small consigments entails organising the cartage work of the L.M.S.R. into convenient « rounds » or trips, so as to obtain economical use of cartage equipment, and similarly it entails sorting the traffic in goods sheds to gather together sufficient consignments between pairs of points to make a convenient wagon load, for which purpose a ton was regarded as a reasonable minimum figure, subject to certain special arrangements.

The new zonal scheme for collection and delivery services described in this article is being introduced with the primary object of providing a one-day transit for miscellaneous traffic between most points by concentrating the handling of such traffic at a smaller number of stations. At the same time, there will be a system of road services radiating from the various zonal centres and rail-

heads by which consignments arriving from other zones too late for completing their journey by rail that day, will be taken on to the consignee by road vehicle, instead of waiting at the goods station for the next wagon departure and being delayed by, perhaps, 24 hr. before reaching their final address by rail and local delivery service. Traffic passing between points in the same zone may be handled throughout by rail or road, or by a combination of the two according to which method is most convenient for expeditious delivery.

Steps were taken also to accelerate the transit of large numbers of small consignments between the larger transhipdepots and the small station at which the traffic was ultimately required, by use of road motors on the day of arrival at the transhipdepot, instead of sending on by rail wagon, which generally meant that the traffic did not arrive at the ultimate destination station until the day following receipt at the transhipdepot. Similar arrangements existed in respect

Unloading at a consignee's premises.

Before describing the scheme in detail, it is necessary to recapitulate some of the steps taken by the L.M.S.R. before the war to accelerate the handling of miscellaneous traffic, of which the arrangements now being made are in some respects an extension on a scale covering the whole system. Cartage areas in towns had been extended progressively, and at many stations country lorry services provided delivery and collection of miscellaneous traffic at farms and villages within a radius of up to ten miles. Railhead distribution schemes were operated whereby a particular firm's traffic passed in through wagon loads to selected centres, from which points distribution by motor vehicle over large areas of traffic working in the reverse direction between the smaller station and the transhipdepot.

Where possible, and in order to save road motor costs, other consignments were worked by early morning wagons between transhipdepots and ultimate destination in the case of received traffic, and by early evening wagons from the smaller station to the transhipdepot for forwarded traffic.

In view of the great diversity in the traffic itself, and in the points between which it passed, it was not always possible to sort together sufficient traffic to justify sending a wagon from the originating to the destination station. In these cases the traffic was loaded inter-

mediately, usually to a large centre, for transhipment, that is, amalgamation with similar traffic from other points whereby it was possible to make a wagon to destination.

Arising out of the extended area of collection and delivery around large towns and cities already referred to, the L.M.S.R. had conducted research into the best method of performing cartage in the outlying areas of large places where the company had more than one goods station dealing with miscellaneous goods traffic.

Co-ordinating cartage service.

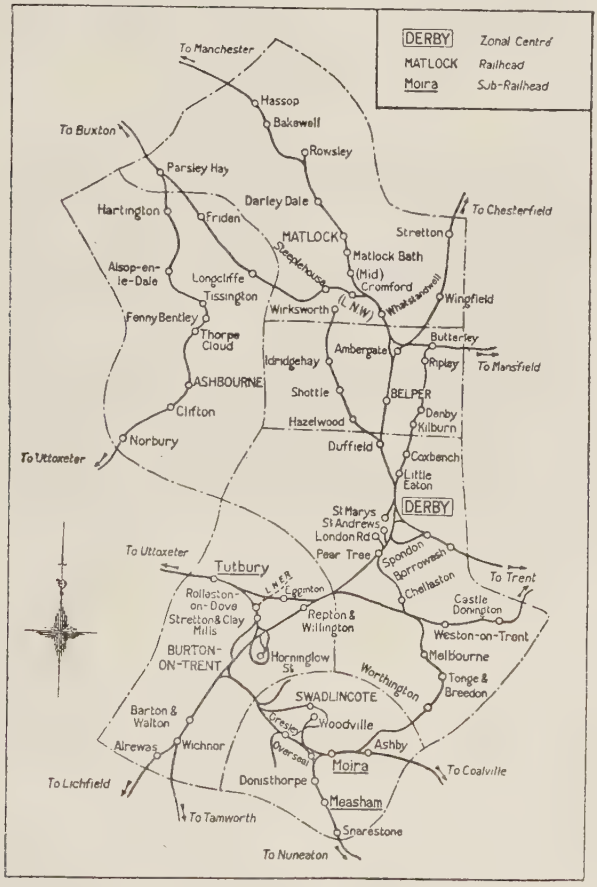
The object was to co-ordinate cartage in the outer areas, instead of each main goods depot serving these areas direct with its own cartage vehicles. The basis of the idea was that a cartage sub-depot should be provided in the outlying area, at which a cartage establishment would be provided for the ordinary door-to-door cartage services, the traffic being conveyed to or from such cartage sub-depots by rail where a good service could be given ; otherwise it was to be conveyed between the main terminals and sub-depots by high-capacity motor vehicles, the « round » sorting being performed at the sub-depots.

A sub-depot of this type for dealing with delivered traffic was planned at Old Ford, London, in 1937, and when war broke out work was in progress on a completely new depot for handling both delivered and collected consignments. Shortage of petrol and tyres necessitated traffic to and from Old Ford being handled by rail throughout the war, but at the present time road services are being

Location of present and proposed zonal centres on the L.M.S.R. in England and Wales.

built up between the main London termini and this sub-depot.

When it seemed that the war in Europe was approaching finality, attention was given to the preparation of a scheme on a more scientific basis, and from this has evolved the zonal collection and delivery scheme. This organisation will supersede the motor services operating pre-war, and instead of the somewhat patchwork arrangements which then existed, a cartage organisation is being built up for the L.M.S.R. system as a whole with the object, not only of equalling, but of improving on pre-war transits. The basis of the scheme is the conception of area cartage as opposed to cartage which tended to be confined to individual places.

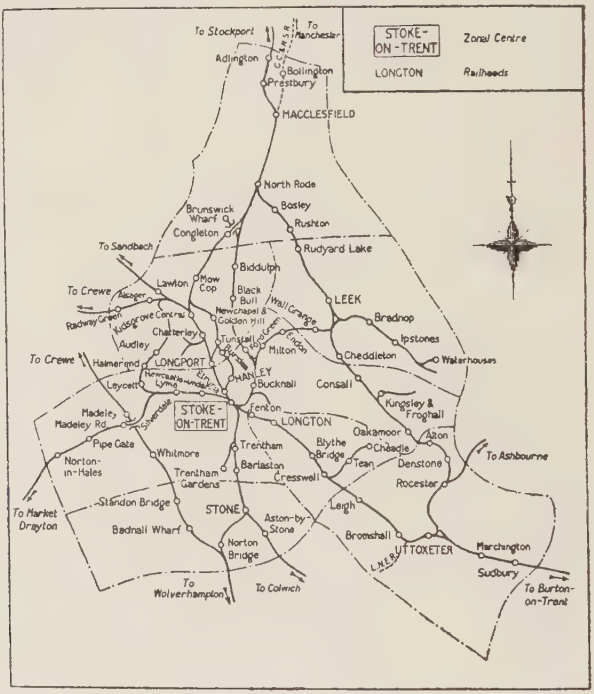


Organisation of the Derby zone. The dotted lines define the five railhead areas, and the extended Derby local delivery area.

Under the new zonal scheme, the territory served by the L.M.S.R. is being divided into a number of contiguous zones, in each of which a large town is selected as a zonal centre. The zonal

centre retains its own local delivery area, which often is being extended, and operates trunk motor services to and from a number of railheads. Each railhead serves a cartage area of approximately 5 to 10 miles radius, these areas, too, being contiguous so that whole of the zone is provided with cartage either

Zone. — The country has been divided into contiguous zones, the size of which varies according to geographical position, density of traffic, and general suitability for train working and cartage operations, ensuring as far as possible a concentration of traffic at a zonal centre without unduly long haulage.



The Stoke-on-Trent zone. Hanley is acting at present as a railhead for its immediate vicinity within the Stoke local area.

from the zonal centre or from a railhead. In some circumstances, where the area to be served by a railhead is large, a sub-railhead is established for collection and delivery of traffic in districts which are at an excessive distance from the railhead itself. The functions of the zonal centre, railhead, and sub-railhead, and the manner in which they receive and dispose of traffic, are summarised below :

Zonal Centre. — This is the main centre for each zone, and will receive traffic by wagon for subsequent distribution to its railheads and sub-railheads by trunk motor, or by rail, and for direct delivery within a prescribed portion of the zone. In the reverse direction, the zonal centre will receive traffic from its railheads and sub-railheads by trunk motor, or by rail (so long as the desired transit is achieved), and will

dispose of the traffic by wagon. Traffic passing from sender to consignee both resident within the same zone, may be sent by road transport throughout, or part rail and part road.

Railhead. — A railhead will function for collection and delivery of traffic within a prescribed portion of the zone. It will receive its miscellaneous traffic by trunk motor, or by rail from its own zonal centre, or by direct wagon from other zonal centres, railheads, or sub-railheads. The railhead will dispose of its outwards traffic by : (*a*) direct wagon to destination sub-railhead, railhead, or zonal centre; or (*b*) trunk motor or wagon to its own zonal centre.

Sub-Railhead. — A sub-railhead will function for collection and delivery of traffic within a prescribed portion of a railhead area, where the distance from the railhead is too great to allow of direct collection or delivery therefrom. It will receive inwards traffic by : (*a*) direct wagon from another sub-railhead, railhead, or zonal centre; (*b*) trunk motor or wagon from parent railhead. It will dispose of its outwards traffic by : (*a*) direct wagon to destination sub-railhead, railhead, or zonal centre; or (*b*) trunk motor to parent railhead or wagon to parent railhead or zonal centre.

An important feature of the scheme is the reduction that will be effected in the number of stations at which it will be necessary to maintain a cartage establishment for handling miscellaneous traffic, and this is one of the economies that can be offset against the increased road cartage expenditure entailed by the scheme as a whole. Accommodation no longer required at such stations is being rented or sold at several places, and this principle will be extended as the scheme develops. Stations in this category are referred to as « absorbed » stations.

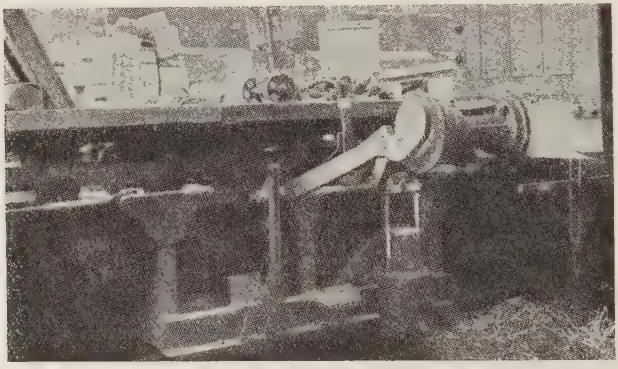
Unloading with a mechanical conveyor at Derby St. Mary's, with drays for internal movement to sorting points alongside.

Absorbed stations will continue to accept traffic brought in by the public, but will dispose of it to the road services of the appropriate railhead, sub-railhead, or zonal centre, which will call at such stations when necessary.

Further economies will result from a saving in shunting and engine trips arising from the smaller number of stations at which it will be necessary to position wagons specially in the goods

shed. There will be a reduction, also, in transhipment, with consequent economies in handling costs and wagon user.

In very sparsely populated districts the expense of motoring could not be justified, and the small quantity of miscellaneous traffic concerned will continue to be dealt with by tariff van services. This constitutes an extremely small percentage of the miscellaneous traffic.



Electric « mule » used for movement of wagons over short distances inside the shed at St. Mary's.

The Derby zone.

Two zones in which the new arrangements already are well advanced are those based on Derby and Stoke-on-Trent. Derby operates trunk road services to five railheads, located at Swadlincote, Ashbourne, Burton, Belper, and Matlock.

The Derby local delivery area has been extended in order to join up with the adjacent railhead areas, and now covers Worthington, Castle Donington, Borrowash, Spondon, and Duffield. Borrowash is an absorbed station, the motor previously located there having been brought into Derby. Altogether, there are 36 absorbed stations in the zone. Three sub-railheads have been established, at Tutbury Measham, and Moira, which are served by extensions of the trunk road services from Derby to Burton and Swadlincote respectively.

On the basis of results achieved so far, figures have been computed showing an annual saving of 172 000 wagon-miles in the Derby zonal scheme.

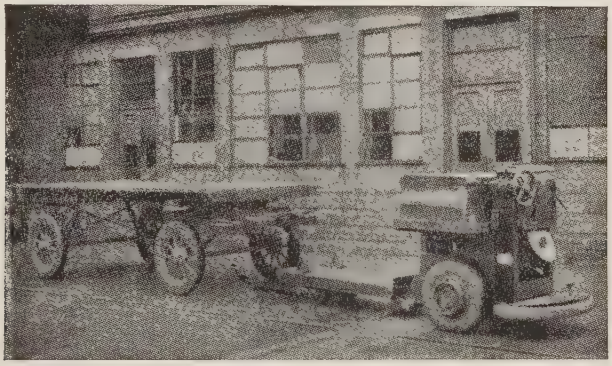
Miscellaneous traffic for the Derby zone is dealt with at St. Mary's goods station, which was completed shortly after the beginning of the war. The shed has a floor area of 4 acres, and deals with approximately 250 inwards and 250 outwards wagons daily. Part of this is transhipment traffic, Derby being an example of a transfer depot, a number of which will be necessary under the zonal scheme to handle traffic which cannot be loaded direct from forwarding to destination zone. Such depots will be established in the main at zonal centres, and will dispose of traffic usually by wagon.

St. Mary's is provided with four inwards and ten outwards roads. The inwards roads are situated in pairs at each side of the shed, with a « throw-away » road between each pair and electric traversers to shift wagons into position for movement to the unloading bays, and to

transfer them to the throw-away roads when empty. There are two conveyor-type unloading machines, designed by the L.M.S.R. Mechanical Department, at each side of the shed. After unloading, consignments undergo a preliminary sorting into delivery and transfer items (including those going on to stations in the zone by wagon) on the unloading bay, after which zonal traffic is removed on drays for final sorting according to whether it is to be disposed of by local or trunk road delivery services.

short distances such as from the buffer stops to the unloading point, is a pair of travelling jaws which runs along the front face of the platform at such a height as to engage with the wagon buffer. The « mules » also have remote control on the deck.

Very little alteration or new work has been required at St. Mary's for handling traffic under the zonal scheme. Two new bays have been provided, and some extension of the butting strip from which the road vehicles depart will be under-



Electric truck and internal goods shed dray, with automatic coupling mechanism to form an articulated unit.

Much of the haulage of the drays in the shed is performed by electric trucks, provided with automatic coupling and uncoupling mechanism which simultaneously raises the front wheels of the dray off the ground so that it forms an articulated unit with the truck. Time-saving has been studied equally in respect of horse-drawn drays, the shafts forming part of the horse's harness, so that it is necessary only to back on to the vehicle, when coupling up is automatic.

Movement of wagons inside the shed is accomplished by specially designed electric « closed loop » capstans, with push-button control from the deck, and by electric « mules ». The « mule », which is used for shifting wagons over

taken, but as high-capacity motor transport becomes available, it will be possible to accommodate more at the existing strip so that large additions are not required. Derby, however, is fortunate in having a modern mechanised shed, and some other zonal centres will have to undertake a larger programme of improvements.

Arrangements at Stoke-on-Trent.

The Stoke-on-Trent zone eventually will have trunk road services radiating both from Stoke and Crewe, and a total of 83 stations will be absorbed. Eight of these places are now served directly by extending the Stoke delivery area.

At Tunstall, which is now served from the railhead at Longport, several advantages to the railway and to traders have been obtained.

The new status of Tunstall as an absorbed station has enabled the company to effect economy in engine power. Elsewhere in the zone, the handling of goods by road between Stoke, Stone, Newcastle-under-Lyme, and Standon Bridge has resulted in the cancellation of a freight train between Crewe and Norton Bridge on three days a week.

Stoke, at present, is operating trunk road services to Uttoxeter, Leek, Longton, Longport, Stone, and Hanley. It is proposed to bring other routes into operation in due course. In a similar manner to Derby, the Stoke local delivery area has been extended to include Barlaston, Bucknall, Consall, Endon, Kingsley & Froghall, Milton, Oakamoor, Trentham, Trentham Gardens, and other local stations.

No new structural work is required in the goods shed at Stoke to operate the scheme, but extra cartage berth accommodation may be necessary at railheads.

The Longport railhead possesses already a spacious outwards shed which was built during the war, and deals with some 55 wagons a day. In this shed the incoming road vehicles load directly into the wagons, sorting being carried out in the course of the rounds by the checker. There are four overhead electric cranes, three of 30-cwt. and one of 7 tons capacity. Figures of the annual economies that will be realised in the Stoke zone show a saving of 99 000 wagon-miles.

The L.M.S.R. is at present operating zonal collection and delivery schemes covering more than 300 stations, the clerical, handling, and cartage work connected with consignments dealt with under the arrangements being centralised at the respective railhead or sub-railheads. The experience gained makes it clear beyond any measure of doubt that the setting up at selected centres of zonal collection and delivery arrangements has been justified on commercial grounds, in that the primary object, the improvement of transits and deliveries of small consignments, has been attained. The schemes are, therefore, making a useful contribution to the development of the nation's trade, which is the paramount need of today.

Inside the goods shed at Hanley, one of the railheads now operating in the Stoke-on-Trent zone.

[385. (09 (.489)]

The centenary of the Danish State Railways.

(Note issued by the Danish State Railways Press Service.)

On June 27th 1947, the Danish State Railways celebrated their centenary to commemorate the commencement of railway-traffic in the present Denmark, as the service was opened on the line Copenhagen-Roskilde (30 km. — 19 miles) on June 27th 1847 after a solemn inauguration the day before (traffic on the line Kiel-Altona in the Danish monarchy of those days was already opened in 1844).

The first Danish railways on Zealand (Copenhagen-Roskilde 1847, Roskilde-Korsor 1856 and further extensions in the sixties and seventies) were constructed and managed as private railways. The same held good of the first railways in Jutland and Fuenen, which in the sixties were constructed by English engineers. Already in 1867, the Government took over the railways in Jutland-Fuenen and in 1880 those on Zealand. In 1885, the State-owned lines were thus amalgamated into what they are to-day: *The Danish State Railways.*

The railways have during this centenary been the subject of an extensive and radical development. It has not only during the first 75 years been a question of an enormous extension of the network and opening of train-ferry-services (later on supplanted by bridges), but the technical plants have constantly been developed, the rolling-stock increased and frequently exchanged for new types in order, at any moment, to cope with all legitimate claims.

The mileage was :

1847 — 30 km. (19 miles),
1867 — 475 » (295 »),
1887 — 1 555 » (970 »),
1907 — 2 029 km. (1 260 miles),
1927 — 2 614 » (1 624 »),
1947 — 2 595 » (1 612 »).

During roughly speaking the last 15 years some lines with a small amount of traffic were closed. Within the same period, however, the State Railways have taken over a number of motorbus-services, the mileage of which to-day is abt. 3 100 km. (1 926 miles). Besides railways and bus-services the Danish State Railways run 8 train-ferry and boat services, 4 in connection with Sweden/Norway and Germany respectively. Across 3 waterways (the « Storstrommen », the Little Belt and « Oddesund ») which were formerly served by train-ferries, great bridges have now been built (the « Storstrombridge » 3 200 m. (10 500 ft.) and the Little Belt-bridge 825 m. (2 706 ft.).

As a single instance of the development it should be pointed out that the track in 1847 consisted of wrought-iron (weight 29 kgr. [64 lbs] per m., length 5.49 m. [18 ft.]) resting directly on oak-sleepers in turn resting on gravel. The present track on the main-lines consists of steel-rails (weight 60 kgr. [132 lbs] per m., length 60 m. [197 ft.]) fastened by screws to creosoted beech-sleepers on stone-ballasting.

As far as the motive-power of to-day is concerned, there is not much resemblance between the original 4 locomotives and the present park of 760 locomotives and motorcoaches, besides 8 special Diesel-electric motor-coach-units (« streamlined trains »). The weight of the biggest steam-locomotives is 4 times that of the original ones in 1847, their capacity is multiplied and

running-power greatly enhanced too (in the case of the express train stock to 120 km. [74 miles]/h.).

The rolling-stock has kept pace with the development. Not only the numbers but also the capacity of the vehicles has been increased, and as far as carriages are concerned the comfort of the travellers has to a marked degree been attended to, inter alio by introducing upholstered seats in the 3rd class (« general class » as we call it in Denmark).

Among the first European railway-systems the Danish State Railways adopted already by the end of the century electric train-lighting. In the course of the last decade the park of wagons and trucks were equipped with compressed-air-brake.

The principal train-ferry-service (the Great Belt) has been the subject of an essential improvement through the introduction of triple-tracked motor-ferries of a length of approx. 110 m. (360 ft.) and abt. 6 000 H.P.

During the century the number of employees rose from abt. 100 to approx. 27 000, of which 17 000 are civil servants and the like and 10 000 temporary staff. Out of the total working-expenditure of the State Railways in 1945-46 (approx. 250 millions Kroner), the pay-roll on an average amounted to 60 %. The average-income of the total staff taken as a whole was in the same year roughly 6 000 Kroner.

The financial results have been greatly fluctuating. For a number of pre-war years, apart from writings-off and interest on the construction-cost, the revenues and expenditures were brought to a fairly good balance. The special traffic in the years of occupation: 1940-45 resulted on the books in very considerable net-profits, employed for extraordinary writings-off. In the century in question taken at large, the actual expenditures on an average amounted to 87 % of the revenues.

Mainly during the last years of occupation the State Railways were subjected to a lot of acts of sabotage serving the purpose of preventing or at any rate delaying the German transports. The number of track-explosions reached 8 000 and numerous signal-boxes etc. were destroyed. As a whole the damage has however been repaired, let alone the fact that the reconstruction of several plants works out slowly. The maintenance-work, which during and partly after the war suffered a setback and the delayed development of plants and stock cause, here as everywhere, very considerable difficulties; and the intermittent lack of fuel-supplies has rendered necessary a cutting down of the time-tables, which in the case of passenger-trains, so far, only amounts to 75 % of pre-war services.

The number of passengers carried on the State Railways was in the latest Fiscal Year approx. 81 millions, half of which were users of the suburban network of Copenhagen (whereof 42 km. [26 miles] are electrified). Approximately 10 million tons of merchandise (on which freight was paid) were transported during the same year.

Apart from the State Railways nearly 2 500 km. (1 553 miles) of lines are run as private lines, chiefly of a secondary importance. The construction of these private lines was as a rule supported to some extent by the government through participation in the construction-cost, whereas the government formerly did not partake of working-deficits, if any, which the municipalities have thus had to defray.

NEW BOOKS AND PUBLICATIONS.

[**621** .132 .3 (.68) & **621** .132 .5 (.68)]

4-8-2 class « 15F » locomotives for the South African Railways. An 8-page brochure (8½″ × 11″), with text, illustrations and general arrangement diagram, reprinted from the *Railway Gazette*, 33, Tothill St., Westminster, London, S.W.1. (Price 2 s. 0 d.)

This brochure is a reprint of a descriptive article which appeared in the *Railway Gazette* dated the 20th. September, 1946, from which we have extracted the following main points:

At the beginning of 1946 the North British Locomotive Co. completed the construction of 60 locomotives of this type for the South African Railways. Together with the 44 similar ones built before the war, they comprise a large stock of powerful locomotives, capable of reaching a speed of 60 miles per hour and of hauling 540-tons passenger trains over gradients of 12.5 mm (1 in 80), which are numerous on the South African system. Goods trains of over 1 000 tons can also be hauled by these locomotives.

They were built to the design and instructions of Dr. M. M. Loubser, Chief Mechanical Engineer of the South African Railways. Inspection was undertaken by the Consulting Engineer to the High Commissioner in London.

The first 4-8-2 locomotive, class 15, was put into service in South Africa in 1914. This original design had a grate area of 40 sq. ft., a boiler pressure of 185 lbs/sq. in., 4′9″ driving wheels and a maximum axle load of 16½ tons.

The power of the 4-8-2 locomotives built since 1914 has increased progressively, and improvements rendered necessary by the services and by maintenance have been incorporated in the design.

The latest example to be built will have possibly the highest power which in practice may be reached with a 4-8-2 wheel arrangement on a 3′6″ gauge, with an axle load limited to 18½ tons.

The principal characteristics of the new locomotives are as follows:—

Cylinders (2), dia. × stroke	24 in. × 28 in.
Coupled wheels, dia.	5 ft.
Wheelbase, rigid	15 ft. 9 in.
Axleload	18.5 tons.
Adhesive weight	73 tons.
Adhesive factor (at 75 per cent. T.E.)	3.86
Weight of engine and tender (in working order)	179 tons 14 cwt.
Boiler pressure	210 lb. per sq. in.

Heating surface:	
Tubes—	
36 flue, $5^{11}/_{16}$ in. out. dia. and 136 small $2\frac{1}{2}$ in. out. dia.	3 179 sq. ft.
Firebox (incl. arch tubes)	235.5 »
Total evaporative	3 414.5 »
Superheater — $1\frac{1}{2}$ in. dia. tubes	661 »
Total	4 075.5 »
Tractive effort at 85 per cent. B.P.	47 980 lb.
Tractive effort at 75 per cent. B.P.	42 340 lb.
Grate area	62.5 sq. ft.
Coal capacity	14 tons.
Water capacity	6 050 gal.

The boiler weighs 35 tons. It is the largest in the world for a straight-type locomotive on a 3'6" gauge track. The grate area is practically the largest possible for a 4-8-2 locomotive. A mechanical stoker can be fitted when circumstances permit.

The boiler has no dome, as this would foul the loading gauge. The steam collector consists of a number of small rising pipes arranged along half the length of the barrel.

Steel firebox.

M.L.S. superheater, combined with regulator having multiple valves on the saturated steam side.

Bar-type frames.

The cylinders have cast-iron liners, but the rear covers are of cast steel.

Air valves, by-pass and steam valve operated by the driver for running with closed regulator.

Walschaerts valve gear. Piston valves, 12" diameter, $7^{3}/_{8}$" stroke.

Hydrostatic lubricators.

Laird crossheads and slide bars. Special steel connecting rods with lubrication by thick grease and floating bushes.

Normal springing with equalising bars.

Roller bearing axleboxes for bogies and bissel truck.

Vacuum brakes on the locomotive and tender.

Stones electric lighting.

The very spacious tender has two bogies with Isothermos axleboxes. The tanks are of welded construction.

Alliance automatic couplings for the first 45 engines, with Murray friction drawgear. As rubber became more plentiful, the remaining locomotives were fitted with Spencer-Moulton drawgear.

[385 .3 (.42)]

Railway Inspection. — A booklet (5 1/8″ × 7 7/8″) of 24 pages. — 1946, published by *The Railway Gazette*, 33, Tothill Street, Westminster, London S.W. 1. (Price : 1s./—).

In this little book the editor of the well known periodical *The Railway Gazette* gives a short history of the organisation of Government inspection of the British Railways.

In the preface the author stresses the fact that even in the early years and afterwards throughout the whole development of the railway system, there have been very few accidents, and the increase in speed has not led to an increase in risks, as those knowing little of the operating methods might fear. No important legislative measures were passed regarding safety before 1868, in which year it was made obligatory to have some means of communication between passengers and train staff. In 1871, the powers of the Board of Trade were extended and detailed, but in spite of several accidents which occurred in the following years, no other measures were taken until the serious accident at Armagh in 1889 on the Great Northern of Ireland; the block system, interlocking equipment, and continuous automatic brakes were then made obligatory.

The chief characteristic of English legislation has been to intervene as little as possible in technical questions, leaving great freedom of action as regards investigation into methods of improving the stock and equipment. In view of the high degree of safety of the passenger services for many years, it is not likely that Great Britain will make any change in her attitude in this connection.

The law of 1871, amended by that of 1933 (Road & Rail Traffic Act, 1933) covers the question of railway inspection. The chief interest of the work lies in the opinions quoted from various authorities who have had to express their views on different methods of intervention. Thus, as regards the inspection of the permanent way, before it is put into service and during operation, the reader will note the report of the Royal Commission of 1865, which states that the organisation of frequent visits by Government inspectors instead of the normal steps taken by responsible Companies is to be avoided.

Precise official instructions lay down which accidents must be reported by the Company. Accidents form the subject of an enquiry carried out by an inspector, and the Ministry of Transport (which has taken the place of the Board of Trade since 1919) can give the report whatever publicity is considered advisable. The publication of the report is considered very important in Great Britain, as it is held that public opinion is thus enabled to force the Companies to take whatever steps are necessary. The Minister of Transport can also allow any qualified person, even a magistrate, to hold the enquiry, but in practice this is rarely done. An annual report is presented by the Chief Inspecting Officer to the Ministry and submitted to Parliament. In conformity with the views of Sir John Pringle who modified the form in 1901, this report is generally brief and concise, and deals more with the causes of accidents than with their number and gravity, in order to draw conclusions which will be profitable for the future by the analysis of individual negligence or the failure of equipment.

E. M.

[385. (02]

The Railway Handbook. — 1946-1947. — Compiled by the Editor of *The Railway Gazette.* — A brochure (5½″ × 8¼″) of 120 pages. — 1946, London, The Railway Publishing Company Limited, 33, Tothill Street, Westminster, S.W. 1. (Price : 5s./—).

The purpose of this annual publication, first issued in 1934, is to give in popular form at low price, a great deal of information, chiefly statistical, about the English Railways.

A return to more normal conditions has made it possible to publish various statistics which were not available for the last seven years. Amongst others mention may be made of a table summing up the reports of the railways for each year from 1938 to 1945, showing the comparative situation as regards rolling stock and the main traffic elements.

Comparative figures for the staff are available for the years 1938, 1939, 1944 and 1945.

The English Railways, as is generally known, were amalgamated into four Companies by the law of 1921 (Railways Act. 1931).

A brief history is given to show how each Company was constituted. The constitution of the London Passenger Transport Board which includes all the London metropolitan railways as well as the London tramway and omnibus services, is also analysed. Similar information is given for most of the minor companies and the Irish Railways.

The financial results of the whole of the railways for the years 1922 to 1938 are made clear by summarised statistics, which also include the evolution of the passenger and goods traffic.

The large share of the railways in road transport undertakings and omnibus companies will be specially noted.

A table of serious accidents from 1840 describes the nature of each accident and the number of casualties.

Although the book is chiefly reserved for data concerning the English Railways, information will also be found therein regarding the railways of the rest of the world. For example we are given the mileage of the railways in the various countries in each continent (from 1840 to 1937), the highest altitude reached by railways, the longest tunnels, the fastest runs, the longest non-stop runs, the longest straight sections of line, the mileage of electrified lines throughout the world, a table comparing the various loading gauges. A special note gives details of the speed records reached on the English Railways.

Mention may also be made of a succinct report on the present position of signalling in England, and a note on the different methods of traction used : steam, electric and diesels.

For those interested in technical English publications, there is a comprehensive bibliography giving details of articles in periodicals and books dealing with the economics, history, operation and technical equipment of railways.

Finally mention may be made of a brief chronological table of the most remarkable facts in the history of the railways in various countries and events of international interest.

This brief review, which needs must pass over in silence many interesting aspects of the book, will no doubt make it clear that it would be hard to collect together a great amount of valuable information in such a small volume.

E. M.

[656 .25 (.42)]

Railway Signalling and Communications. — Installation and maintenance. — One volume ($5\frac{1}{2}'' \times 8\,11/16''$) of 408 pages, copiously illustrated. — 1946, London, The St. Margaret's Technical Press Limited, 33, Tothill Street, Westminster, S.W.1. (Price : 8s./— net.)

This book, published by the St. Margaret's Technical Press Ltd., London, contains the text of a series of lectures given to the staff of the London & North Eastern Railway in the Company's technical schools by members of the signalling staff.

The value of such lectures is undisputed; safety installations on the railways have been developed to such an extent that the staff in charge of their installation and maintenance must have a much wider knowledge than previously.

Although the subjects covered refer principally to the equipment used on the London & North Eastern Railway, the book will be of value to the staff of other railways. It contains a very succinct report of the mechanical an electrical laws which all categories of staff must know in order to understand theoretical details and calculations, as well as the working of the equipment.

The book begins by detailing the considerations which led to the installation of safety equipment on railway lines. It recalls the regulations imposed by the Ministry of Transport in this connection, as well as the methods used to assure the necessary degree of safety.

A detailed description is then given of the devices used to work and control the signals — operating levers, transmission wires, slots, indicators showing the position of the points — mechanical transmission by rods, including interlocking and compensating devices, as well as interlocking of the signals and points and crossings.

The protection of level crossings with various other safety devices is the subject of a special chapter.

The maintenance of mechanical signalling equipment leads to a description of the faults which may occur, as well as the steps to be taken to assure the proper working of the equipment at all times.

Different chapters are then devoted to the description of electrical equipment for assuring the safe running of trains, telegraphic point equipment, single or three wire blocks, teleprinters, single line safety equipment, telephone apparatus, etc...

The installation and maintenance of telegraph and telephone lines, the principles and practice of track circuits using direct or alternating current, and finally the special circuits for electric signals are all described in details.

The book, which has been very carefully edited, is illustrated by many diagrams and photographs.

J. V. R.

[313 .385 (.42)]

L.N.E.R. Statistics. — Railways, Roads, Canals. — A brochure ($3\frac{1}{2}'' \times 6''$) of 32 pages, published by the *London & North Eastern Railway, 1946.*

This pamphlet is a collection of operating statistics and financial results. Most of the numerical tables contain data relating to the L.N.E.R. and in addition to the English main line railways as a whole. In some cases the latter element of comparison is replaced by a figure relating to « all Companies », i.e. covering all the lesser railways, but not the lines operated by the London Passenger Transport Board.

Most of the comparisons made are between the years 1938 and 1945. When necessary figures for a certain number of other years also are given. This is so in particular in the case of the table giving the average percentage of dividends compared with capital receipts for the years 1933 to 1945.

The Chief General Manager who is responsible for the publication of this pamphlet points out that the work relates to a period on which the « blackout » on statistics has recently been lifted, but it is stil partially enforced and consequently there are certain restrictions.

The reader must also take into account the fact that the running of the railways as a « pool » during the war makes any valid comparison with prewar years impossible, as no exact division of the gross receipts could be made.

In addition, owing to the 1941 Control Agreement, the net revenue was also frozen.

Such as they are, however, in spite of these reservations, the statistics given are of great interest. They make it possible to get easily and quickly an idea of the activity and importance of the English railways.

It is certain that there will be no difficulty over the condition which the author stipulates must be fulfilled if the pamphlet is to be published annually, i.e. sufficient demand.

E. M.

[623 (.42)]

Longmoor Military Railway. — Transportation Training Centre of the Corps of Royal Engineers. — A pamphlet ($6'' \times 9\,1/16''$) of 22 pages, illustrated. — 1946, London, *The Railway Gazette,* 33, Tothill Street, Westminster, S.W. 1. (Price : 2s./—).

This pamphlet is a reprint of an article published by *The Railway Gazette* after a visit by press representatives to the Royal Engineers' Camp at Longmoor in Hampshire, England.

During this visit those invited were able to see the most interesting equipment and were given some idea of the methods and principles used.

They heard a report from the Commander, Brigadier C. A. Langley, C.B.E., M.C., who described the history of the Camp and its activities in the past, particularly during the war which has just ended. This report, which is given in full, forms the main part of the pamphlet.

The training which the recruits undergo covers all branches of railway activity : levelling the ground and building the railway, including installations; operating (movement of trains and utili-

sation of locomotives); maintenance and repair shops. The training of the men is intended to be above all practical, with as little theoretical instruction as possible. Consequently they are usually given work which shows immediate practical results.

During the war Longmoor Military Camp was the scene of great activity. Many thousands of men were trained there before being sent to the various theatres of war.

The pamphlet is illustrated by well chosen drawings. For example a 320 ft. span of an Everall sectional struss bridge is shown being assembled.

In this pamphlet *The Railway Gazette* has succeeded in giving its readers a very exact idea of the work carried out at Longmoor, and it is a well deserved tribute to those who have contributed to its efficacity.

E. M.

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PUBLISHED UNDER THE SUPERVISION OF

P. GHILAIN,

General Secretary of the Permanent Commission of the International Railway Congress Association.

(SEPTEMBER 1947)

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SIRAGHI (G.). — Le **ferrovie** negli Stati Uniti nerica. (4 000 parole & fig.)

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NSONI (R.) & SOTTILE (A.). — **Fondazioni su** per il ponte ferroviario provvisorio a Sesto Calende. 0 parole & fig.)

In Dutch.

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MEYER (A. G.). — « **Anderhalfdekkers** » voor de Island Railroad. (1 000 woorden & fig.)

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r- en Tramwegen, Nr 23, 15 Augustus, p. 278.
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PATER (A. D.). — De van de Zwitsersche Spoor- n overgenomen **locomotieven der N. S.** serie 3000, 5600, 7800 en 7850. (1 600 woorden. tabellen & fig.)

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KORVER (J. J.). — De **herstelling van oorlogschade** aan den weg, de kunstwerken en de gebouwen. (2 000 woorden & fig.)

1946 **621 .335 (.44) & 621 .431 .72 (.44)**
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In Norwegian. (= 439.82.)

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1947 **725 .31 (.481) = 439 .82**
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LØKEN (K.). — **Central station of Oslo.** (1 700 words & fig.)

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OFTEDAHL (C.). — Analysis of **concrete.** (1 700 words & fig.)

1947 **624 .1 = 439 .82**
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ENGELBRETH (K.). — **Foundation** problems. (1 600 words & fig.)

In Portuguese.

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1947 **385. (09 (.469)**
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Fusão das Emprêsas ferroviárias. Alguns elementos para o estudo do problema português. (2 000 palavras.)

1947 **621 .33**
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1947 **385 .15**
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VIEIRA DE CASTRO (A.). — **Nacionalizações, fusões e reorganizações** de vias férreas. (2 200 palavras.)

1947 **621 .33**
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VIEIRA DE CASTRO (A.). — A miragem da **tracção eléctrica** nas grandes linhas férreas. (6 000 palavras.)

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1946 **624 .2**

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BORGES (J. Ferry E. S.). — Estudo experimental do campo de tensões pela **rotura duma camada aderente.** (2 500 palavras & fig.)

1946/47 **62. (01 & 691**

Tecnica, nº 169, dezembro, p. 59; nº 170, janeiro, p. 123.

DE SOUSA COUTINHO (A.). — Determinação de **tensões no betão** pelo mitodo do tensómetro fotoelâstico. (15 000 palavras, cuadros & fig.)

1946/47 **62. (01 & 721 .9**

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CANSADO DE CARVLHO (E.). — Calculo dum silo rectangular de **betão armado.** (5 000 palavras, cuadros & fig.)

1947 **53**

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ROCHA (M.). — A fisica e a **engenharia civil.** (4 000 palavras & fig.)

1947 **721 .1**

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MAYER (A.). — Les applications de la mécanique des sols et l'étude des **fondations.** (8 000 mots & fig.)

In Swedish. (= 439.71.)

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1947 **621 .133 .2 (.485) = 439 .71**
[& 621 .392 (.485) = 439 .71

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NIKLASSON (S.). — **Electric welding of copper fireboxes for locomotives.** (6 200 words & fig.)

1947 **659 (.73) = 43**

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SJÖBERG (A.). — **Publicity organization of Ame railroads.** (4 900 words & fig.)

1947 **385. (072 (.481) = 43**

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LÖKKE (O. A.). — Section C meeting at Stockl — Lecture: **The Laboratory in the service of rail** (4 400 words & fig.)

P. 173, Danish report, by Mr. von HERBST (1 100 words.)

P. 175, Finnish report, by M. ROSS (T.). (500 wo

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1947 **656 .28 (.485) = 43**

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HARD (T.). — **Railway accident report** : Gardsj June 29th, 1945. (3 800 words & fig.)

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1947 **624 .42 (.73) = 43**

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ZETTERSTRÖM (O.). — **American underground road systems.** (1 700 words & fig.)

1947 **625 .42 (.73) = 43**

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ZETTERSTRÖM (O.). — **New York undergroun roads.** (500 words & fig.)

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Modern English steam locomotives. (400 words &

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